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15. SUPPLEMENTARY NOTES This report discusses the regulatory alternatives considered during development of the proposed new source performance standards and the environmental and economic impacts associated with each regulatory alternative.

16. ABSTRACT

Standards of Performance for the control of VOC emissions from the rubber tire manufacturing industry are being proposed under Section 111 of the Clean Air Act. These standards would apply to the following cement application operations: undertread cementing, sidewall cementing, tread end cementing, bead cementing, inside green tire spraying, and outside green tire spraying. This document contains background information and environmental and economic impact assessments of the regulatory alternatives considered in developing the proposed standards.

17. KEY WORDS AND DOCUMENT ANALYSIS

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Rubber Tire Manufacturing Industry — Background Information for Proposed Standards

Emission Standards and Engineering Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air, Noise, and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

July 1981

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ENVIRONMENTAL PROTECTION AGENCY

Background Information
and Draft
Environmental Impact Statement
for Rubber Tire Manufacturing Industry

Prepared by:

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1. The proposed standards of performance would limit emissions of volatile organic compounds (VOC) from new, modified, and reconstructed facilities in rubber tire manufacturing plants. Section 111 of the Clean Air Act (42 U.S.C. 7411), as amended, directs the Administrator to establish standards of performance for any category of new stationary source of air pollution that ". . . causes or contributes significantly to air pollution which may reasonably be anticipated to endanger public health or welfare."

2. Copies of this document have been sent to the following Federal Departments: Labor, Defense, Transportation, Commerce, Interior, and Energy; the Council on Environmental Quality; members of the State and Territorial Air Pollution Program Administrators; the Association of Local Air Pollution Control Officials; EPA Regional Administrators; and other interested parties.

3. The comment period for review of this document is 60 days. Ms. Susan R. Wyatt may be contacted regarding the date of the comment period.

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1.0 SUMMARY

Background information on proposed new source performance standards for the rubber tire manufacturing industry is contained in this document. New source performance standards are proposed under authority of Sections 111 and 301(a) of the Clean Air Act, as amended.

1.1 REGULATORY ALTERNATIVES

Review of the technical support data (Chapters 2 through 5) led to the selection of two regulatory alternatives. Chapter 6 presents a detailed description of and reasoning for the choice of these alternatives. Regulatory Alternative I represents the level of control of volatile organic compound (VOC) emissions that would be in effect in the absence of additional regulation. This alternative would rely on State Implementation Plans (SIPs) to regulate all new, modified, and reconstructed rubber tire manufacturing operations. A typical SIP for rubber tire manufacturing operations would require an average reduction of 70 percent for uncontrolled VOC emissions from undertread cementing, tread end cementing, bead cementing, and organic solvent-based green tire spraying. VOC emission reductions under Regulatory Alternative I are achievable using VOC capture/control (emission reduction) systems.

Regulatory Alternative II would require that uncontrolled VOC emissions from undertread cementing, sidewall cementing, tread end cementing, and bead cementing be reduced by at least 75 percent. It is based on the use of emission reduction systems for each operation. Under Regulatory Alternative II, emissions from organic green tire spraying operations would be reduced 90 percent from average uncontrolled levels by substitution with water-based sprays.

1.2 ENVIRONMENTAL IMPACT

No decrease from baseline VOC emission levels would result from Regulatory Alternative I, since the alternative represents no additional regulation. Regulatory Alternative II would result in decrease of annual VOC emissions from rubber tire manufacturing operations by about 1,700 megagrams (Mg) (1,880 tons) during the fifth-year of the standard: this represents a 55 percent reduction from projected baseline VOC emissions from new, modified, and reconstructed operations. Secondary pollutant emissions from VOC control devices, water pollution, solid waste disposal, energy consumption, and noise impacts are anticipated to be insignificant. Chapter 7 of this document presents an in-depth analysis of fifth-year environmental impacts for Regulatory Alternatives I and II. The results of this analysis are summarized by the matrix presented in Table 1-1.

1.3 ECONOMIC IMPACT

No increase in capital costs to the rubber tire manufacturing industry would be incurred under Regulatory Alternative I, as the alternative represents no additional regulation. Regulatory Alternative II would require that an additional $7.8 million be spent by the tire industry during the first five years of the standard for the purchase and installation of emission reduction systems employing carbon adsorbers. If direct flame afterburners or catalytic afterburners are installed, additional capital costs incurred by the tire industry through the first five years of the standard would be approximately $8.7 million and $13.1 million, respectively.

Regulatory Alternative II would result in additional fifth-year annualized costs of $1.5 million if credits are given for VOCs that are recovered by emission reduction systems using carbon adsorbers; $2.3 million would be spent if no recovery credits are given. Fifth-year annualized costs attributable to Regulatory Alternative II would be $6.3 million if direct flame afterburners are used and $6.0 million if catalytic afterburners are employed.

In the worst case scenario (use of direct flame afterburners in a VOC emission reduction system serving a single operation), pass-through of costs attributable to Regulatory Alternative II would result in an increase of $0.11 in the average price of a radial passenger tire by the fifth year of the standard. Under the worst case presented for Regulatory Alternative II, if the expected return on investment (ROI) in the fifth year were 5 percent, it would decrease from a 5 percent baseline level to about 4.86 percent.

TABLE 1-1. ASSESSMENT OF ENVIRONMENTAL AND ECONOMIC IMPACTS FOR EACH REGULATORY ALTERNATIVE CONSIDERED

Regulatory Alternative	Air Impact	Water Impact	Solid Waste Impact	Energy Impact	Noise Impact	Economic Impact
I	0	0	0	0	0	0
II	+2**	-1**	-1**	-1**	0	-2**

Key:

+	Beneficial Impact
-	Adverse Impact
0	No impact
1	Negligible Impact
2	Small Impact
3	Moderate Impact
4	Large Impact
*	Short-Term Impact
**	Long-Term Impact
***	Irreversible Impact

Chapters 8 and 9 of this document present an analysis of the cost and economic impacts of Regulatory Alternatives I and II. The results of the analysis are summarized by the matrix presented in Table 1-1.

2.0 INTRODUCTION

2.1 BACKGROUND AND AUTHORITY FOR STANDARDS

Before standards of performance are proposed as a Federal regulation, air pollution control methods available to the affected industry and the associated costs of installing and maintaining the control equipment are examined in detail. Various levels of control based on different technologies and degrees of efficiency are expressed as regulatory alternatives. Each of these alternatives is studied by EPA as a prospective basis for a standard. The alternatives are investigated in terms of their impacts on the economics and well-being of the industry, the impacts on the national economy, and the impacts on the environment. This document summarizes the information obtained through these studies so that interested persons will be able to see the information considered by EPA in the development of the proposed standard.

Standards of performance for new stationary sources are established under section 111 of the Clean Air Act (42 U.S.C 7411) as amended, hereinafter referred to as the Act. Section 111 directs the Administrator to establish standards of performance for any category of new stationary source of air pollution which "... causes, or contributes significantly to air pollution which may reasonably be anticipated to endanger public health or welfare."

The Act requires that standards of performance for stationary sources reflect, "... the degree of emission reduction achievable which (taking into consideration the cost of achieving such emission reduction, and any non-air quality health and environmental impact and energy requirements) the Administrator determines has been adequately demonstrated for that category of sources." The standards apply only to stationary sources, the construction or modification of which commences after regulations are proposed by publication in the Federal Register.

The 1977 amendments to the Act altered or added numerous provisions that apply to the process of establishing standards of performance.

1. EPA is required to list the categories of major stationary sources that have not already been listed and regulated under standards of performance. Regulations must be promulgated for these new categories on the following schedule:
   a. 25 percent of the listed categories by August 7, 1980.
   b. 75 percent of the listed categories by August 7, 1981.
   c. 100 percent of the listed categories by August 7, 1982.

A governor of a State may apply to the Administrator to add a category not on the list or may apply to the Administrator to have a standard of performance revised.

2. EPA is required to review the standards of performance every four years and, if appropriate, revise them.

3. EPA is authorized to promulgate a standard based on design, equipment, work practice, or operational procedures when a standard based on emission levels is not feasible.

4. The term "standards of performance" is redefined, and a new term "technological system of continuous emission reduction" is defined. The new definitions clarify that the control system must be continuous and may include a low- or non-polluting process or operation.

5. The time between the proposal and promulgation of a standard under Section 111 of the Act may be extended to six months.

Standards of performance, by themselves, do not guarantee protection of health or welfare because they are not designed to achieve any specific air quality levels. Rather, they are designed to reflect the degree of emission limitation achievable through application of the best adequately demonstrated technological system of continuous emission reduction, taking into consideration the cost of achieving such emission reduction, any non-air quality health and environmental impacts, and energy requirements.

Congress had several reasons for including these requirements. First, standards with a degree of uniformity are needed to avoid situations where some States may attract industries by relaxing standards relative to other States. Second, stringent standards enhance the potential for long-term growth. Third, stringent standards may help achieve long-term cost savings by avoiding the need for more retrofitting when pollution ceilings may be reduced in the future. Fourth, certain types of standards for coal-burning sources can adversely affect the coal market by driving up the price of low-sulfur coal or effectively excluding certain coals from the reserve base because their untreated pollution potentials are high. Congress does not intend that new source performance standards contribute to these problems. Fifth, the standard-setting process should create incentives for improved technology.

Promulgation of standards of performance does not prevent State or local agencies from adopting more stringent emission limitations for the same sources. States are free under section 116 of the Act to establish even more stringent emission limits than those established under section 111 or those necessary to attain or maintain the National Ambient Air Quality Standards (NAAQS) under section 110. Thus, new sources may in some cases be subject to limitations more stringent than standards of performance under section 111, and prospective owners and operators of new sources should be aware of this possibility in planning for such facilities.

A similar situation may arise when a major emitting facility is to be constructed in a geographic area that falls under the prevention of significant deterioration of air quality provisions of Part C of the Act. These provisions require, among other things, that major emitting facilities to be constructed in such areas are to be subject to best available control technology. The term Best Available Control Technology (BACT), as defined in the Act, means

> ... an emission limitation based on the maximum degree of reduction of each pollutant subject to regulation under this Act emitted from, or which results from, any major emitting facility, which the permitting authority, on a case-by-case basis, taking into account energy, environmental, and economic impacts and other costs, determines is achievable for such facility through application of production processes and available methods, systems, and techniques, including fuel cleaning or treatment or innovative fuel combustion techniques for control of each such pollutant. In no event shall application of "best

> available control technology" result in emissions of any pollutants which will exceed the emissions allowed by any applicable standard established pursuant to section 111 or 112 of this Act. (Section 169(3))

Although standards of performance are normally structured in terms of numerical emission limits where feasible, alternative approaches are sometimes necessary. In some cases physical measurement of emissions from a new source may be impractical or exorbitantly expensive. Section 111(h) provides that the Administrator may promulgate a design or equipment standard in those cases where it is not feasible to prescribe or enforce a standard of performance. For example, emissions of hydrocarbons from storage vessels for petroleum liquids are greatest during tank filling. The nature of the emissions, high concentrations for short periods during filling and low concentrations for longer periods during storage, and the configuration of storage tanks make direct emission measurement impractical. Therefore, a more practical approach to standards of performance for storage vessels has been equipment specification.

In addition, section 111(i) authorizes the Administrator to grant waivers of compliance to permit a source to use innovative continuous emission control technology. In order to grant the waiver, the Administrator must find: (1) a substantial likelihood that the technology will produce greater emission reductions than the standards require or an equivalent reduction at lower economic energy or environmental cost; (2) the proposed system has not been adequately demonstrated; (3) the technology will not cause or contribute to an unreasonable risk to the public health, welfare, or safety; (4) the governor of the State where the source is located consents; and (5) the waiver will not prevent the attainment or maintenance of any ambient standard. A waiver may have conditions attached to assure the source will not prevent attainment of any NAAQS. Any such condition will have the force of a performance standard. Finally, waivers have definite end dates and may be terminated earlier if the conditions are not met or if the system fails to perform as expected. In such a case, the source may be given up to three years to meet the standards with a mandatory progress schedule.

2.2 SELECTION OF CATEGORIES OF STATIONARY SOURCES

Section 111 of the Act directs the Administrator to list categories of stationary sources. The Administrator "... shall include a category of sources in such list if in his judgment it causes, or contributes significantly to, air pollution which may reasonably be anticipated to endanger public health or welfare." Proposal and promulgation of standards of performance are to follow.

Since passage of the Clean Air Amendments of 1970, considerable attention has been given to the development of a system for assigning priorities to various source categories. The approach specifies areas of interest by considering the broad strategy of the Agency for implementing the Clean Air Act. Often, these "areas" are actually pollutants emitted by stationary sources. Source categories that emit these pollutants are evaluated and ranked by a process involving such factors as: (1) the level of emission control (if any) already required by State regulations, (2) estimated levels of control that might be required from standards of performance for the source category, (3) projections of growth and replacement of existing facilities for the source category, and (4) the estimated incremental amount of air pollution that could be prevented in a preselected future year by standards of performance for the source category. Sources for which new source performance standards were promulgated or under development during 1977, or earlier, were selected on these criteria.

The Act amendments of August 1977 establish specific criteria to be used in determining priorities for all major source categories not yet listed by EPA. These are: (1) the quantity of air pollutant emissions that each such category will emit, or will be designed to emit; (2) the extent to which each such pollutant may reasonably be anticipated to endanger public health or welfare; and (3) the mobility and competitive nature of each such category of sources and the consequent need for nationally applicable new source standards of performance.

The Administrator is to promulgate standards for these categories according to the schedule referred to earlier.

In some cases, it may not be feasible immediately to develop a standard for a source category with a high priority. This might happen when a program of research is needed to develop control techniques or because techniques for sampling and measuring emissions may require refinement. In the developing of standards, differences in the time required to complete the necessary investigation for different source categories must also be considered. For example, substantially more time may be necessary if numerous pollutants must be investigated from a single source category. Further, even late in the development process the schedule for completion of a standard may change. For example, inability to obtain emission data from well-controlled sources in time to pursue the development process in a systematic fashion may force a change in scheduling. Nevertheless, priority ranking is, and will continue to be, used to establish the order in which projects are initiated and resources assigned.

After the source category has been chosen, the types of facilities within the source category to which the standard will apply must be determined. A source category may have several facilities that cause air pollution, and emissions from some of these facilities may vary from insignificant to very expensive to control. Economic studies of the source category and of applicable control technology may show that air pollution control is better served by applying standards to the more severe pollution sources. For this reason, and because there is no adequately demonstrated system for controlling emissions from certain facilities, standards often do not apply to all facilities at a source. For the same reasons, the standards may not apply to all air pollutants emitted. Thus, although a source category may be selected to be covered by a standard of performance, not all pollutants or facilities within that source category may be covered by the standards.

2.3 PROCEDURE FOR DEVELOPMENT OF STANDARDS OF PERFORMANCE

Standards of performance must (1) realistically reflect best demonstrated control practice; (2) adequately consider the cost, the non-air-quality health and environmental impacts, and the energy requirements of such control; (3) be applicable to existing sources that are modified or reconstructed as well as new installations; and (4) meet these conditions for all variations of operating conditions being considered anywhere in the country.

The objective of a program for developing standards is to identify the best technological system of continuous emission reduction that has been adequately demonstrated. The standard-setting process involves three principal phases of activity: (1) information gathering, (2) analysis of the information, and (3) development of the standard of performance.

During the information-gathering phase, industries are queried through a telephone survey, letters of inquiry, and plant visits by EPA representatives. Information is also gathered from many other sources, and a literature search is conducted. From the knowledge acquired about the industry, EPA selects certain plants at which emission tests are conducted to provide reliable data that characterize the pollutant emissions from well-controlled existing facilities.

In the second phase of a project, the information about the industry and the pollutants emitted is used in analytical studies. Hypothetical "model plants" are defined to provide a common basis for analysis. The model plant definitions, national pollutant emission data, and existing State regulations governing emissions from the source category are then used in establishing "regulatory alternatives." These regulatory alternatives are essentially different levels of emission control.

EPA conducts studies to determine the impact of each regulatory alternative on the economics of the industry and on the national economy, on the environment, and on energy consumption. From several possibly applicable alternatives, EPA selects the single most plausible regulatory alternative as the basis for a standard of performance for the source category under study.

In the third phase of a project, the selected regulatory alternative is translated into a standard of performance, which, in turn, is written in the form of a federal regulation. The federal regulation, when applied to newly constructed plants, will limit emissions to the levels indicated in the selected regulatory alternative.

As early as is practical in each standard-setting project, EPA representatives discuss the possibilities of a standard and the form it might take with members of the National Air Pollution Control

Techniques Advisory Committee. Industry representatives and other interested parties also participate in these meetings.

The information acquired in the project is summarized in the Background Information Document (BID). The BID, the standard, and a preamble explaining the standard are widely circulated to the industry being considered for control, environmental groups, other government agencies, and offices within EPA. Through this extensive review process, the points of view of expert reviewers are taken into consideration as changes are made to the documentation.

A "proposal package" is assembled and sent through the offices of EPA Assistant Administrators for concurrence before the proposed standard is officially endorsed by the EPA Administrator. After being approved by the EPA Administrator, the preamble and the proposed regulation are published in the Federal Register.

As a part of the Federal Register announcement of the proposed regulation, the public is invited to participate in the standard-setting process. EPA invites written comments on the proposal and also holds a public hearing to discuss the proposed standard with interested parties. All public comments are summarized and incorporated into a second volume of the BID. All information reviewed and generated in studies in support of the standard of performance is available to the public in a "docket" on file in Washington, D. C.

Comments from the public are evaluated, and the standard of performance may be altered in response to the comments.

The significant comments and EPA's position on the issues raised are included in the "preamble" of a "promulgation package," which also contains the draft of the final regulation. The regulation is then subjected to another round of review and refinement until it is approved by the EPA Administrator. After the Administrator signs the regulation, it is published as a "final rule" in the Federal Register.

2.4 CONSIDERATION OF COSTS

Section 317 of the Act requires an economic impact assessment with respect to any standard of performance established under section 111 of the Act. The assessment is required to contain an analysis of:

(1) the costs of compliance with the regulation, including the extent to which the cost of compliance varies depending on the effective date of the regulation and the development of less expensive or more efficient methods of compliance; (2) the potential inflationary or recessionary effects of the regulation; (3) the effects the regulation might have on small business with respect to competition; (4) the effects of the regulation on consumer costs; and (5) the effects of the regulation on energy use. Section 317 also requires that the economic impact assessment be as extensive as practicable.

The economic impact of a proposed standard upon an industry is usually addressed both in absolute terms and in terms of the control costs that would be incurred as a result of compliance with typical, existing State control regulations. An incremental approach is necessary because both new and existing plants would be required to comply with State regulations in the absence of a federal standard of performance. This approach requires a detailed analysis of the economic impact from the cost differential that would exist between a proposed standard of performance and the typical State standard.

Air pollutant emissions may cause water pollution problems, and captured potential air pollutants may pose a solid waste disposal problem. The total environmental impact of an emission source must, therefore, be analyzed and the costs determined whenever possible.

A thorough study of the profitability and price-setting mechanisms of the industry is essential to the analysis so that an accurate estimate of potential adverse economic impacts can be made for proposed standards. It is also essential to know the capital requirements for pollution control systems already placed on plants so that the additional capital requirements necessitated by these federal standards can be placed in proper perspective. Finally, it is necessary to assess the availability of capital to provide the additional control equipment needed to meet the standards of performance.

2.5 CONSIDERATION OF ENVIRONMENTAL IMPACTS

Section 102(2)(C) of the National Environmental Policy Act (NEPA) of 1969 requires federal agencies to prepare detailed environmental impact statements on proposals for legislation and other major federal actions significantly affecting the quality of the human environment. The objective of NEPA is to build into the decision-making process of federal agencies a careful consideration of all environmental aspects of proposed actions.

In a number of legal challenges to standards of performance for various industries, the United States Court of Appeals for the District of Columbia Circuit has held that environmental impact statements need not be prepared by the Agency for proposed actions under section 111 of the Clean Air Act. Essentially, the Court of Appeals has determined that the best system of emission reduction requires the Administrator to take into account counter-productive environmental effects of a proposed standard, as well as economic costs to the industry. On this basis, therefore, the Court established a narrow exemption from NEPA for EPA determination under section 111.

In addition to these judicial determinations, the Energy Supply and Environmental Coordination Act (ESECA) of 1974 (PL-93-319) specifically exempted proposed actions under the Clean Air Act from NEPA requirements. According to section 7(c)(1), "No action taken under the Clean Air Act shall be deemed a major Federal action significantly affecting the quality of the human environment within the meaning of the National Environmental Policy Act of 1969." (15 U.S.C. 793(c)(1))

Nevertheless, the Agency has concluded that the preparation of environmental impact statements could have beneficial effects on certain regulatory actions. Consequently, although not legally required to do so by section 102(2)(C) of NEPA, EPA has adopted a policy requiring that environmental impact statements be prepared for various regulatory actions, including standards of performance developed under section 111 of the Act. This voluntary preparation of environmental impact statements, however, in no way legally subjects the Agency to NEPA requirements.

To implement this policy, a separate section in this document is devoted solely to an analysis of the potential environmental impacts associated with the proposed standards. Both adverse and beneficial impacts in such areas as air and water pollution, increased solid waste disposal, and increased energy consumption are discussed.

2.6 IMPACT ON EXISTING SOURCES

Section 111 of the Act defines a new source as "... any stationary source, the construction or modification of which is commenced..." after the proposed standards are published. An existing source is redefined as a new source if "modified" or "reconstructed" as defined in amendments to the general provisions of Subpart A of 40 CFR Part 60, which were promulgated in the Federal Register on December 16, 1975 (40 FR 58416).

Promulgation of a standard of performance requires States to establish standards of performance for existing sources in the same industry under section 111(d) of the Act if the standard for new sources limits emissions of a designated pollutant (i.e., a pollutant for which air quality criteria have not been issued under section 108 or which has not been listed as a hazardous pollutant under section 112). If a State does not act, EPA must establish such standards. General provisions outlining procedures for control of existing sources under section 111(d) were promulgated on November 17, 1975, as Subpart B of 40 CFR Part 60 (40 FR 53340).

2.7 REVISION OF STANDARDS OF PERFORMANCE

Congress was aware that the level of air pollution control achievable by an industry may improve with technological advances. Accordingly, section 111 of the Act provides that the Administrator "... shall, at least every 4 years, review and, if appropriate, revise..." the standards. Revisions are made to assure that the standards continue to reflect the best systems that become available in the future. Such revisions will not be retroactive, but will apply to stationary sources constructed or modified after the proposal of the revised standards.

3.0 THE TIRE MANUFACTURING INDUSTRY

3.1 INTRODUCTION

For the purposes of this document, rubber tire manufacturing means the mass production of rubber tires in an assembly-line fashion. Types of tires produced in this manner to be included in the definition are any agricultural, airplane, industrial, mobile home, light-duty truck and passenger vehicle tires which have a bead diameter up to and including 0.5 meter (19.7 inches) and cross section dimension up to 0.325 meter (12.8 inches). Production of heavy-duty truck tires and other large tires requires specialized equipment and is on a much smaller scale than the tire types under consideration in this document. Consequently, these larger tire types are not addressed in this document.

Basically, tire manufacturing consists of the production of component parts, assembly of these components into a raw "green" tire, curing, and finishing to yield a complete tire. Pneumatic rubber tires are constructed from relatively strong fibers, such as nylon, polyester, rayon, glass, aramid, or steel. The fibers are impregnated with both natural and synthetic rubber and overlaid with a tread of wear-resistant polymer, such as styrene-butadiene rubber (SBR). Tires are assembled individually by skilled builders and cured in a heated mold under pressure into the familiar doughnut shape.

Obviously, there are many different tire types and sizes. Tire plants are usually not dedicated to the production of one size class or "series." Moreover, the type of tire manufactured may vary with the seasons: during summer and fall, tire plants may produce a larger proportion of snow tires to build up inventories for the ensuing winter months. Plants may use the same line of equipment to manufacture more than one tire type or series. When necessary, the appropriate machinery is adjusted in order to accommodate the different tires.

Most available tire manufacturing emissions data do not differentiate between various tire types.[1-25] For illustrative purposes, the existing emissions data are related to a representative tire which is based on an average weight. Hence, the emission information can be expressed in units of mass per tire. Total tire industry production presented in Table 3-1 shows that approximately 80 percent of all tires manufactured in the United States as of January 1980 were designated for passenger car use. Industry-supplied data indicate the mean weight of a passenger tire in 1977 to be about 11.5 kilograms (25.3 pounds).[1-14] One tire industry representative has reported that the average tire weight in 1979 has decreased to 11.0 kilograms (24.3 pounds) and predicted further weight reduction as the newer glass belted radials are produced.[26] Although no tire type produced may weigh precisely 11.5 kilograms, it is useful to approximate the weight of the average tire manufactured in the U.S. for comparison of emissions from different tire production steps.

3.1.1 Tire Manufacturing Plants

Listed in Table 3-1 are the United States tire companies' manufacturing plants and the estimated 1979 tire production for each plant.[27] Daily production for the entire industry as of January 1, 1980, was 984,100 tires per day, down approximately 4 percent from the previous year.[27,28] The Gates Rubber Company left the tire industry in 1976. Since 1978, 17 tire manufacturing plants have closed or have been scheduled to close.[27-34] During the period of 1977 to 1978, six plants were closed by Firestone, Goodyear, Mansfield, Mohawk, and Uniroyal. Armstrong, Firestone, Goodyear, Mansfield, and Uniroyal have announced that 11 additional plants will be closed by the end of 1981.[32-34]

Since 1976, the plans for, or actual start-up of, six plants have been announced by General, Goodyear, and Michelin.

Plant expansions by Armstrong, Firestone, Goodrich, and Goodyear had been announced or were in operation as of January 1, 1979.[27-34] Table 3-2 lists tire plant openings, closings, and expansions.

3.1.2 Industry Trends

Table 3-3 shows the number of passenger car and truck tires shipped for the original equipment and the replacement tire markets

Table 3-1. ESTIMATED TIRE PRODUCTION BY PLANT AS OF JANUARY 1, 1980[27]

Company	Plant Location	Tires Produced Thousands/Day[a] Passenger Tires	All Other	Total Tires
Armstrong Rubber Company	Des Moines, IA	10.0	4.5	14.5
	Hanford, CA	11.0	---	11.0
	Natchez, MS	8.0	5.5	13.5
	West Haven CT	12.0	---	12.0
	Nashville, TN	8.5	9.0	17.5
		49.5	19.0	68.5
Cooper Tire and Rubber Company	Findlay, OH	8.4	6.0	14.4
	Texarkana, AR	16.6	4.5	21.1
		25.0	10.5	35.5
Denman Rubber Manufacturing Company	Warren, OH	0.2	4.2	4.4
Dunlop Tire and Rubber Company	Buffalo, NY	10.0	4.0	14.0
	Huntsville, AL	18.0	---	18.0
		28.0	4.0	32.0
Firestone Tire and Rubber Company	Akron, OH	---	4.5	4.5
	Albany, GA	25.0	1.5	26.5
	Bloomington, IL	---	0.1	0.1
	Decatur, IL	23.5	3.8	27.3
	Des Moines, IA	17.0	5.0	22.0
	Los Angeles, CA	1.0	2.0	7.3
	Memphis, TN	14.5	6.2	20.7
	Nashville, TN	---	1.9	1.9

Table 3-1. ESTIMATED TIRE PRODUCTION BY PLANT AS OF JANUARY 1, 1980[27] (Continued)

		Tires Produced Thousands/Day[a]		
Company	Plant Location	Passenger Tires	All Other	Total Tires
Firestone Tire and Rubber Company (Continued)	Pottstown, PA	21.0	3.0	24.0
	Salinas, CA	16.3	2.3	18.6
	Wilson, NC	15.8	---	15.8
		134.1	30.3	164.4
Firestone Subsidiaries				
Dayton Tire and Rubber Company	Dayton, OH	12.5	6.1	18.6
	Oklahoma City, OK	19.2	3.4	22.6
Sieberling Tire & Rubber Company	Barberton, OH	6.5	3.5	10.0
		38.2	13.0	51.2
General Tire and Rubber Company	Akron, OH	---	8.5	8.5
	Bryan, OH	---	0.1	0.1
	Charlotte, NC	19.0	---	19.0
	Mayfield, KY	25.0	9.0	34.0
	Mt. Vernon, IL	12.5	0.5	13.0
	Waco, TX	15.7	4.9	20.6
		70.2	23.0	93.2
B.F. Goodrich Company	Akron, OH	---	0.5	0.5
	Ft. Wayne, IN	18.4	7.1	25.5
	Miami, OK	5.6	7.0	12.6
	Oaks, PA	18.0	1.0	19.0
	Tuscaloosa, AL	33.5	---	33.5
		75.5	15.6	91.1

Table 3-1. ESTIMATED TIRE PRODUCTION BY PLANT AS OF JANUARY 1, 1980[27] (Concluded)

		Tires Produced Thousands/Day[a]		
Company	Plant Location	Passenger Tires	All Other	Total Tires
Goodyear Tire and Rubber Company	Danville, VA	---	11.8	11.8
	Gadsden, AL	31.5	17.0	48.5
	Jackson, MI	21.0	1.5	22.5
	Topeka, KS	30.0	5.0	35.0
	Union City, TN	46.0	---	46.0
	Lawton, OK	22.0	---	22.0
		150.5	35.5	185.8
Goodyear Subsidiaries				
Kelly-Springfield Tire Company	Cumberland, MD	4.5	13.0	17.5
	Fayetteville, NC	29.0	0.5	29.5
	Freeport, IL	14.5	5.0	19.5
	Tyler, TX	25.0	---	25.0
		73.0	18.5	91.5
McCreary Tire and Rubber Company	Indiana, PA	---	4.0	4.0
Michelin Tire Corporation	Greenville, SC	25.0	---	25.0
	Spartanburg, SC	---	3.0	3.0
	Dothan, AL	---	2.0	2.0
		25.0	5.0	30.0
Mohawk Rubber Company	Salem, VA	13.0	0.5	13.5
Uniroyal, Incorporated	Ardmore, OK	32.0	---	32.0
	Chicopee Falls, MA	17.2	4.8	22.0
	Detroit, MI	14.0	2.0	16.0
	Eau Claire, WI	20.5	7.0	27.5
	Opelika, AL	13.7	5.8	19.5
		97.4	19.6	117.0
TOTAL		781.6	202.5	984.1

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[a] Dashes indicate plant does not produce type of tire listed.

Table 3-2. ANNOUNCED PLANT EXPANSIONS, NEW PLANTS AND PLANT CLOSINGS SINCE 1976[27-34]

Company	Location	Year
Expansions		
Goodyear	Gadsden, Alabama	1979
Armstrong	Natchez, Mississippi	1978
Firestone	Nashville, Tennessee	1978-1982
Goodrich	Woodburn, Indiana	1980
New Plants		
Goodyear	Lawton, Oklahoma	1979
Michelin	Dothan, Alabama	1979
	Spartanburg, South Carolina	1976
	Lexington, South Carolina	1982
	Lubbock, Texas	1982
General	Akron, Ohio	a
Closings		
Mansfield	Mansfield, Ohio	1978
	Tupelo, Mississippi	1980
Goodyear	Los Angeles, California	1977
	Akron, Ohio	1977-1978
	Conshohocken, Pennsylvania	1979
Firestone	Akron, Ohio (Plant 1)	1981
	Akron, Ohio (Plant 2)	1978
	Los Angeles, California	1980
	Pottstown, Pennsylvania	1980
	Salinas, California	1980
	Barberton, Ohio	1980
	Dayton, Ohio	1980
Uniroyal	Los Angeles, California	1978
	Detroit, Michigan	1980
	Chicopee Falls, Massachusetts	1980
Mohawk	Akron, Ohio	1978
Armstrong	West Haven, Connecticut	1981

[a] Tentative

Table 3-3. ANNUAL SHIPMENTS OF PASSENGER CAR AND TRUCK TIRES FOR ORIGINAL EQUIPMENT AND REPLACEMENT MARKETS[27]

Year	Number of Tires, Millions					
	Passenger Car			Truck		
	Original Equipment	Replacement	Total	Original Equipment	Replacement	Total
1975	40.0	129.0	169.0	8.3	21.4	29.7
1976	50.0	137.0	187.0	9.2	23.4	32.6
1977	58.0	139.0	197.0	11.2	28.5	39.7
1978	56.5	147.0	203.5	12.2	32.0	44.0
1979	51.0	135.0	186.0	10.2	31.8	42.0

for the years 1975 through 1979.[27] During that period, total shipment of truck tires has shown a compound growth rate of approximately 9 percent per year; the growth rate for passenger car tires during the same period was approximately 3 percent per year. Although the total number of tire shipments during 1979 are higher than those for 1975 or 1976, total shipment of tires during 1979 fell approximately 4 percent below 1977 levels and 8 percent below 1978 levels. Declines in tire shipments are attributable to the decrease of automobile sales, a decline in automotive travel and longer lifetime of radial tires.[35]

Table 3-3 shows the proportions of passenger radial, bias, and bias belted tires shipped to original equipment and replacement markets between 1976 and 1979. Radial tire shipments dominated the original equipment market by 1976 and comprised over half the replacement market in 1979.[27] Extended durability and lifetime, improved vehicle handling, and increased gas mileage are characteristics which have allowed radial tires to displace bias and bias-belted tire purchases. Discussion of projected trends in radial tire shipments is presented in Chapter 9.0.

3.1.3 Volatile Organic Compound Emissions

Tire manufacturing plants constitute an industrial source of emissions of volatile organic compounds (VOCs) to the ambient air. Volatile organic compounds are added to rubber components during tire manufacturing in order to aid in mixing, promote elasticity, produce "tack" or stickiness, and "extend" or replace a portion of the raw material. Volatile organic compounds used as solvents are predominantly white gasoline and petroleum naphtha, although heptane, hexane, toluene, xylene, ketones, and esters find some use in the industry, generally in lesser amounts. Boiling points of these non-polar organic solvents range from 30° to 288°C (86° to 550°F). Consequently, most of these compounds evaporate during the manufacturing process: tests performed by the industry have shown that approximately 8 percent of the VOCs applied to the rubber are absorbed.[36,37] In addition, hydrocarbons from rubber materials are volatilized during curing and other high-temperature operations.

The Lower Explosive Limits (LEL) for VOC used in rubber tire manufacturing plants, which aid in determining maximum concentrations of VOCs permitted for fire safety, range from 1.0 to 2.5 percent by volume of air.[38,39] General fire safety practice is to provide a margin of protection by maintaining organic vapor concentrations below 25 percent of the LEL.[39] When more than one organic compound is involved, it is common practice to regard the mixture as consisting of the component with the lowest LEL.[40] Properties of VOCs emitted from rubber tire manufacturing operations are presented in Table 3-4.

3.2 PROCESSES AND THEIR EMISSIONS

A generalized tire manufacturing process consists of: (1) preparation and compounding of raw materials, (2) transformation of the raw materials into tire components, (3) tire component assembly, and (4) molding, curing, and finishing of the assembled components into the marketable product. Figure 3-1 is a pictorial flow diagram which will facilitate better understanding of the tire manufacturing processes. Each of the above production phases may include one or more sources of volatile organic compound (VOC) emissions. Total 1977 VOC emissions from United States tire manufacturing plants have been estimated to be in the range of 56,100 to 72,700 megagrams (61,800 to 80,100 tons) with a mean of 64,400 megagrams (71,000 tons); Table C-1 summarizes 1977 tire manufacturing VOC emission estimates. The mean accounts for approximately 45 percent of the 140,000 Mg of VOCs emitted by all rubber related industries (Standard Industrial Classification [SIC] group 30) operating in the U.S. in 1977.

Table 3-5 lists operations which are sources of volatile organic compounds and the type of material emitted. The first six exhaust streams listed in Table 3-5 contribute 97 percent of all VOCs emitted in a tire manufacturing plant. Green tire spraying, undertread cementing, and sidewall cementing are the largest sources of VOC emissions. Tire building is the fourth most significant source of VOC emissions. However, these emissions are very dilute (0.01-0.32 g/m^3) due to small releases of VOCs from solvent application at many tire building machines, which occupy a significant proportion of the total floor space of a typical

Table 3-4. PROPERTIES OF VOLATILE ORGANIC COMPOUNDS EMITTED FROM RUBBER TIRE MANUFACTURING OPERATIONS[38-40]

Solvent	Chemical Formula	Density at 20°C g/cm^3	Density at 20°C (lb/gal)	Molecular Weight	Molar Volume	Boiling Point °C	Boiling Point (°F)	LEL, Percent by Volume of Air	(ppm)[b]	Employee Exposure Limit mg/m^3	Employee Exposure Limit (ppm)
Naphtha (Petroleum)	C_6H_{14} to C_7H_{16}	0.66	(5.49)	86-100	143-167	30-60	(86-140)	1.40	(10,000)	400	(100)
Trichloroethylene	$CHClCCl_2$	1.46	(12.2)	131	90	87	(199)	a	---	520	(100)
Tetrachloroethylene	CCl_2CCl_2	1.62	(13.5)	166	102	121	(250)	a	---	670	(100)
Pentachloroethane	$CHCl_2CCl_3$	1.67	(13.9)	202	121	162	(324)	a	---	---	---
Carbon Tetrachloride	CCl_4	1.58	(13.2)	153	97	77	(171)	a	---	63	(10)
Toluene	$C_6H_5CH_3$	0.87	(7.24)	92	106	111	(231)	1.27	(14,000)	753	(200)
Xylene	$C_6H_4(CH_3)_2$	0.87	(7.30)	106	122	144	(291)	1.00	(10,000)	434	(100)
Kerosene	$C_{12}H_{26}$ to $C_{18}H_{38}$	---	---	170-255	---	149-288	(300-500)	1.16	(7,000)	---	---
Ethyl Ether	$C_2H_5OC_2H_5$	0.70	(5.84)	74	106	34	(94)	1.70	(18,500)	1,200	(400)
Gasoline	C_5H_{12} to $C_{10}H_{22}$	0.80	(6.68)	72-142	90-177	38-204	(100-400)	1.30	(14,000)	---	---
n-hexane	$CH_3(CH_2)_4CH_3$	0.66	(5.50)	86	130	69	(156)	1.25	---	1,800	(500)
n-heptane	$CH_3(CH_2)_5CH_3$	0.68	(5.71)	100	146	98	(208)	1.00	---	2,000	(500)
Isopropanol	$CH_3CHOHCH_3$	0.79	(6.59)	60	76	83	(181)	2.50	---	980	(400)

[a] Solvent is not considered flammable.

[b] ppm values for the LEL were not available for many of the solvents listed.

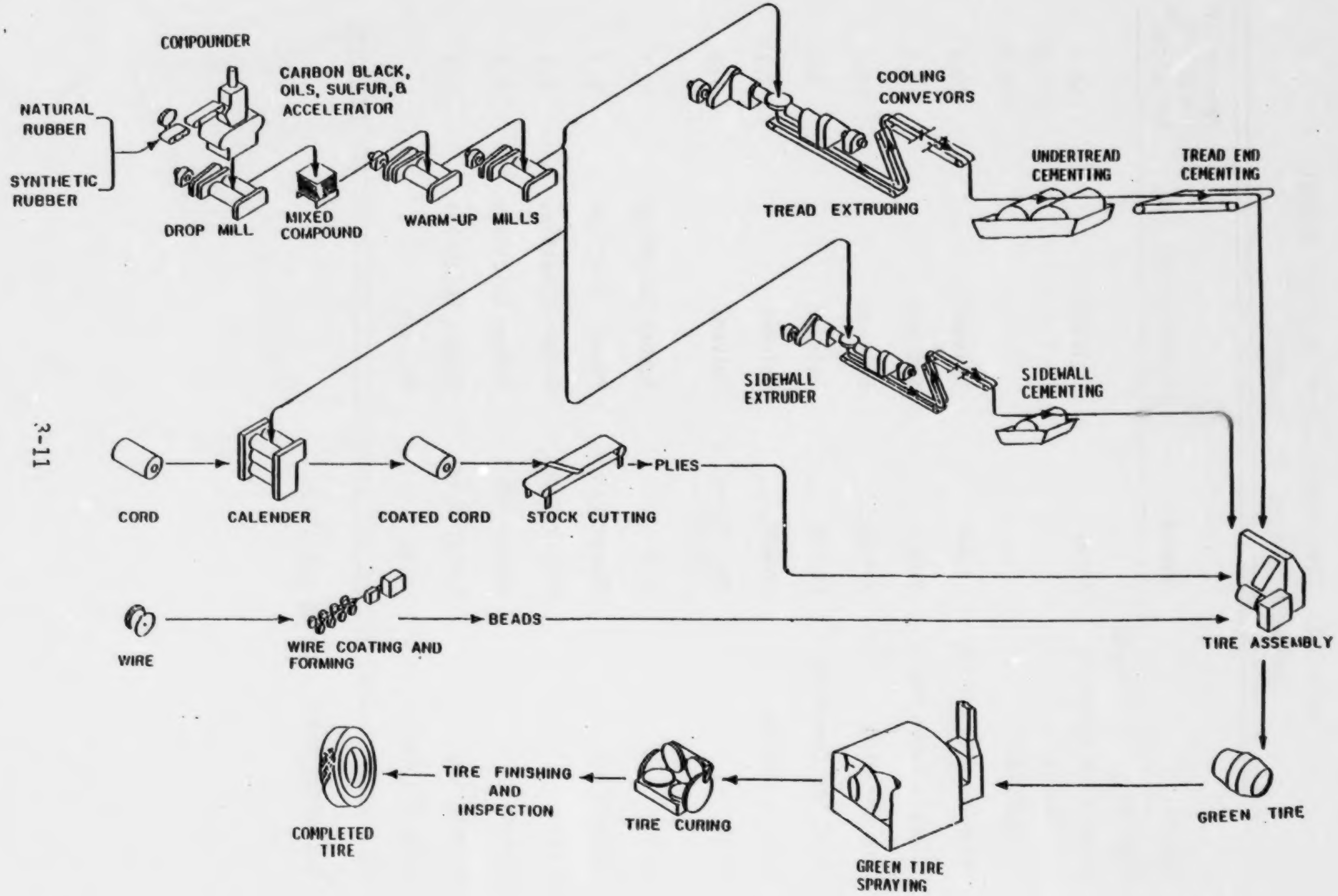

NATURAL RUBBER
SYNTHETIC RUBBER
COMPOUNDER
CARBON BLACK, OILS, SULFUR, & ACCELERATOR
DROP MILL
MIXED COMPOUND
WARM-UP MILLS
TREAD EXTRUDING
COOLING CONVEYORS
UNDERTREAD CEMENTING
TREAD END CEMENTING
SIDEWALL EXTRUDER
SIDEWALL CEMENTING
CORD
CALENDER
COATED CORD
STOCK CUTTING
PLIES
WIRE
WIRE COATING AND FORMING
BEADS
TIRE ASSEMBLY
GREEN TIRE
GREEN TIRE SPRAYING
TIRE CURING
TIRE FINISHING AND INSPECTION
COMPLETED TIRE

Figure 3-1. Tire Manufacturing Flow Diagram

Table 3-5. TIRE MANUFACTURING VOLATILE ORGANIC COMPOUNDS SOURCES AND EMISSIONS[1-25]

Operation	Source	Material Emitted	Percent of Total VOC Emissions[a]
Organic Solvent-Based			
Green Tire Spraying	Spray	Solvent	44.5
(inside)			(15.6)
(outside)			(28.9)
Undertread Cementing	Cement	Solvent	20.5
Sidewall Cementing	Cement	Solvent	13.3
Tire Building	Solvent	Solvent	10.7
Tread End Cementing	Cement	Solvent	4.9
Bead Cementing	Cement	Solvent	2.7
Finishing	Ink, Paint, Spray	Solvent	1.8
Curing	Tire	Rubber Volatiles	0.7
Compounding	Rubber Batch	Rubber Volatiles	0.3
Milling	Rubber Stock	Rubber Volatiles	0.2
Extrusion	Rubber Stock	Rubber Volatiles	0.2
Calendering	Rubber Stock	Rubber Volatiles	0.2
Latex Dipping	Latex	Solvent	-

[a] Excluding latex dipping operation.

tire manufacturing plant.[1-14] Emissions from tread end cementing constitute approximately 5 percent of total VOC emissions in a tire manufacturing plant. Bead cementing operations contribute approximately 3 percent to total in-plant VOC emissions.

Very little emission reduction technology has been employed in the industry. About 40 percent of the VOC emission points in reporting tire plants are hooded for general workroom ventilation. VOC emission reduction systems are known to be installed on the undertread cementing facilities of two plants: one as a retrofit, the other as a part of the original equipment design.[1-14,41] Industry-supplied data indicate many plants have converted green tire spraying operations to accommodate water-based sprays in 1979: approximately 80 percent of all tire production employed water-based inside green tire sprays; about 55 percent used water-based outside sprays.[15-25]

3.2.1 Preparation of Raw Materials

3.2.1.1 Compounding. During compounding, raw crumb rubber is combined with a variety of fillers, extenders, accelerators, antioxidants and pigments, using internal mixing devices. Carbon black and oil are also added during compounding, and baghouse particulate collectors are normally used to control airborne dust generated by this operation.[42] After mixing, the rubber is transferred to roll mills which form the material into sheets. The tacky sheets of rubber stock are then coated with a material such as soapstone to prevent them from sticking together during storage.

VOC emissions from compounding are due to evaporation of curing agents, extenders, accelerators, antioxidants, and unreacted monomers in the base rubber, brought about as a result of heat generated in the mixing process. There are no quantitative data relating materials balance to VOC emissions from compounding; thus, a temperature-weight loss correlation is used as an alternate method for estimating the VOC emission factor (Appendix C). By using an equation derived from the temperature-weight loss correlation for tire curing which was proposed by S.M. Rappaport,[43] an emission factor for compounding of 0.1 g/kg is estimated. Therefore, the estimated average VOC emission factor for compounding the raw material used in an average tire weighing 11.5 kg is 1 gram (0.002 lb) per tire. It should be noted that the temperature-weight loss factor is used only to illustrate the relative magnitude of VOC emissions from compounding.

3.2.1.2 Milling. After compounding, sheeted rubber is fed manually to a warmup roller mill in order to make the stock more flexible for further processing. From the warmup mill, the heated rubber passes to a strip-feed mill for final mixing. The temperature of the rubber mixture leaving the mill is typically 70°C to 90°C.

This is a potential VOC emission point as heat generated by sheet rubber milling may evaporate curing agents, antioxidants, and unreacted monomers from the material. At an operating temperature of 80°C, 50 percent of the volatile organic compounds emitted during milling are assumed to immediately condense to an aerosol.[43] Engineering judgment and tire industry observations attribute this phenomenon to milling temperatures being close to the rubber stock's zero weight loss temperature (critical temperature) of 73.2°C.[44] Based on the use of the Rappaport temperature-weight loss correlation described in Appendix C, an average emission factor for milling is estimated to be 0.6 gram (0.001 lb) per tire. As with the compounding emission factor, the Rappaport temperature-weight loss correlation is used for illustrative purposes.

3.2.2 Component Preparation

Once the rubber stock is compounded and milled, it must be transformed into components from which the tire is built. Component construction involves several parallel operations. Rubber stock and other raw materials, including cord and fabric, are used to make the following components: tire tread and sidewalls, tire cords, tire belts, and tire beads. The tire tread is the part of the tire which contacts the road surface; the design and composition depend on the use of the tire. Sidewalls help anchor the tread and beads as well as provide some strength and protection to the materials which form the tire's pneumatic cushioning. Tire cords are woven synthetic fabrics (rayon, nylon, polyester) which are impregnated with rubber. Tire cords are the body of the tire and supply it with most of its strength. Tire belts stabilize the tires, thus preventing the lateral scrubbing or wiping action that is responsible for tread wear. Tire beads are rubber-coated wires that are in contact with the rim of the wheel on which the tire is mounted. These beads ensure that a proper air seal is maintained around the wheel rim at all times.[42]

3.2.2.1 Tread and Sidewall Preparation. Tread and sidewall components may be formed separately or as a single piece, depending on specifications for a particular tire. When treads and sidewalls are formed as a single component, the two types of rubber stock used to make the treads and sidewalls are peeled from the rollers of separate strip-feed mills and continuously fed to a tread/sidewall extruder. Where white sidewall tires are manufactured, the sidewall components consist of extruded white rubber strips sheathed in a protective coating of black rubber. The tread/sidewall extruder laminates the two strip types to form the tire tread and two sidewalls. Adhesion of the strips is accomplished through heat and pressure generated by a rotating extruder screw. After extrusion, a cushioning layer is added to the underside of the tread/sidewall combination. The continuous strip of rubber is then conveyed to a cementing station.

If tread and sidewall are formed as separate components, separate production lines are used. Production equipment used to manufacture sidewall components is similar to equipment used for tread production. When treads and sidewalls are manufactured separately, the components are not joined until the green tire is constructed in tire building.

Quantitative information on emissions from extrusion in tire manufacturing plants is not available. However, depending on the mass of the extruded product, temperatures between 70°C and 90°C are attained during extrusion due to heat generation by the rotating screw. The rotating screw constitutes a potential VOC emission point as the heat produced during extrusion of the continuous rubber strips may volatilize materials added during compounding. Applying the temperature-weight loss correlation described in Appendix C and employing the assumption that 50 percent of the materials condense immediately after volatilization yields an estimated average emission factor for extrusion of 0.6 gram (0.001 lb) per tire.[43] This value is determined for illustrative purposes only.

3.2.2.1.1 Undertread cementing. The underside of the tread component (tread base) is tackified to aid in tire assembly. After extrusion, the continuous strip of tread is tackified, usually by the felt roller application of a solvent-based cement.[15-25,45,46] Solvents typically used for this purpose include: naphtha, heptane, hexane, some isopropanol, and toluene.[1-25] After cement application, the tread strip is cooled by air drying on a conveyor and/or by passing through a water bath.

Evaporation of solvent from the line's cement holding tank, application assembly, and tread component as it passes along a conveyor after cement application contributes to tire plant VOC emissions. Materials balance calculations and evaporation rate testing have shown that about 70 percent of VOC emissions at undertread cementing originate at the tank area and application equipment; approximately 30 percent of undertread cementing VOC emissions result from solvent evaporating off the cemented rubber.[47] Test results supplied by the industry show that about 90 percent of the solvent applied to the rubber evaporates within 30 seconds. After several minutes of drying, approximately 8 percent of the solvent applied to the rubber remains absorbed and may not be emitted from the coated material for periods exceeding 24 hours.[36,37] It should be noted that the amount of VOC emitted from the cement tank and application assembly, the solvent evaporation rate, and proportion of absorbed solvent may vary from plant to plant, as these parameters are dependent on equipment used, equipment dimensions, ventilation rate, cement type, solvent type, and other work practices.

In order to maintain VOC concentrations in the workplace below Occupational Safety and Health Administration (OSHA) employee exposure limits (Section 3.3.3), industry employs local and general ventilation methods to remove air contaminated by undertread cementing operations. Tire industry-supplied data indicate that exhaust gas flow rates due to ventilation of undertread cementing operations range from 0.6 to 4.4 m^3/sec (1,271 to 9,323 scfm).[1-14] Consequently, VOC concentrations in the undertread cementing exhaust stream vary from approximately 0.7 to 5.0 g/m^3 (90.0×10^{-6} to 310.0×10^{-6} lb/ft^3).[1-14] The number of undertread cementing operations per plant, the exit gas flow rate, temperature, and pressure for those operations which have individual ventilation systems are shown in Appendix C. The calculated annual mass of volatile organic compounds emitted from the undertread cementing facility in each plant is also included. Based on industry-supplied solvent consumption data[1-25,40] and mass-balance calculations included in Appendix C, the mean emission factor for undertread cementing is estimated to be 63.2 grams (0.139 lb) of solvent VOC per tire.

3.2.2.1.2 Sidewall cementing. Where sidewall components are processed separately from undertread components, a continuous strip of sidewall rubber may be tackified to aid in tire assembly. After extrusion, the continuous strip can be tackified, usually by the felt roller application of a solvent-based cement.[15-25,45-46] Solvents typically used for this purpose include: naphtha, heptane, hexane, isopropanol, and toluene.[15-25] After cementing, the sidewall component can be water-cooled and air dried, then rolled in fabric and transported to the appropriate tire building area.

Evaporation of solvent from the line's cement holding tank, application assembly, and cemented rubber sidewall component contributes to VOC emissions. No information is available, but since sidewall operations are similar to undertread operations, it is assumed that about 70 percent of sidewall cementing VOC emissions originate at the application area; approximately 30 percent of the VOC emitted is assumed to evaporate off the rubber. It is also assumed that about 90 percent of the solvent applied to the rubber evaporates within 30 seconds; after several minutes of drying, approximately 8 percent of the applied solvent is assumed to remain absorbed in the rubber material.

In order to maintain VOC concentrations in the workplace below Occupational Safety and Health Administration (OSHA) employee exposure limits (Section 3.3.3.), industry employs some local and general ventilation methods to remove air contaminated by VOC evaporation from sidewall cementing operations. No information is available concerning exhaust gas flow rates and VOC concentrations from sidewall cementing. However, flow rates are expected to be similar to those in undertread cementing. Thus if solvent VOC use is less at sidewall cementing than at undertread cementing, the respective VOC concentrations in exhaust gases should be lower.

The calculated annual mass of VOCs emitted from sidewall cementing operations in each plant is shown in Appendix C. Based on industry-supplied solvent consumption data[1-25] and mass balance calculations included in Appendix C, the mean emission factor for sidewall cementing is estimated to be 41.1 grams (0.091 lb) of solvent VOC per tire.

3.2.2.1.3 Tread end cementing. After undertread cementing, the continuous rubber tread is cut to the specified length for each tire series. The tread ends may be tackified by a solvent-based cement, which is usually applied by either of two methods. The tread ends can be automatically sprayed with cement after undertread cementing and prior to stacking in trays for transport to tire building. Alternatively, cement can be manually applied to the ends of the rubber, either after undertread cementing and prior to stacking, or as the tread is wrapped around the tire building drum. Naphtha, white gasoline, hexane, and heptane are solvents typically used in cements for tread end cementing; isopropanol and toluene are used less frequently.[1-25]

Potential VOC emissions result from: excess sprayed cement, the manual cement holding tank; the manual cement brush, and from the tread ends. Materials balance calculations and evaporation rate testing have shown that about 80 percent of the automatic tread end cementing VOC emissions originate from the application equipment; approximately 20 percent evaporates from the rubber.[48] Approximately 75 percent of manual tread end cementing emissions come from the cement pot and brush; about 25 percent result from solvent applied to the tread ends.[49] Test results supplied by the industry show that about 90 percent of the solvent applied to the rubber evaporates within 30 seconds. After several minutes of drying, approximately 8 percent of the solvent applied to the rubber remains absorbed and may not be emitted from the coated material for periods exceeding 24 hours.[36,37]

The tire industry utilizes local and general ventilation methods to maintain workplace VOC concentrations associated with tread end cementing emission points below OSHA employee exposure limits (Section 3.3.3). Consequently, exhaust flow rates due to ventilation of tread end cementing lines range from 0.8 to 9.4 m^3/sec (1,695 to 19,920 scfm). Resulting VOC concentrations in the tread end cementing exhaust stream vary from 0.02 to 5.20 g/m^3 (1.2×10^{-6} to 324.6×10^{-6} lb/ft^3).[1-14] Appendix C contains emission data for individual tire plant tread end cementing lines. Based on industry-supplied solvent consumption data[1-25] and the mass-balance calculations described in Appendix C, the estimated mean emission factor for automatic tread end cementing is 23.8 grams (0.052 lb) of solvent VOC per tire. The mean emission factor for manual processes is estimated to be 9.9 grams (0.022 lb) of solvent VOC per tire. The combined tread end cementing emission factor, which is calculated by weighting the contribution of VOCs by both cement application methods on a plant-by-plant basis, is estimated to be 15.1 grams (0.033 lb) per average tire.

3.2.2.2 Latex Dipping. Tire cords and belts are constructed from woven synthetic fabrics, such as nylon, polyester, and rayon, as well as steel and glass fiber. Upon arrival at a tire manufacturing plant, a roll of fabric is first spliced, either by adhesive or by a high-speed sewing machine, onto the tail of the previously processed roll. This continuous sheet of fabric is then fed under controlled tension to a latex dip tank. After latex dipping, the fabric travels past either rotating beater bars or vacuum suction lines and then through a drying oven to remove excess solvent.[42]

Tire manufacturers tend to be producing less and purchasing more fabric which has been dipped in latex at a textile mill. Some of the reasons for this trend are:[42]

1) a small dipping operation requires disproportionately large capital expenditures;

2) latex dipping is a high-speed process which can readily over-supply a tire plant with fabric; and

3) on a weight basis, shipping costs for dipped and undipped fabric are nearly the same.

In accordance with the above, only one tire plant has reported consumption of solvent for on-site latex dipping. Therefore, no VOC emissions have been calculated for this process.

3.2.2.3 Calendering. The latex dipped fabric is passed through a calendering machine which impregnates the fabric with rubber. Both sides of the fabric can be coated simultaneously by four-roll calenders, which are the most commonly used type in the tire manufacturing industry; three-roll calenders are used less frequently as they can coat only one side of the fabric at a time. Before being sent to the tire building facility, the rubberized fabric is cooled and cut to the proper angle and length for the tires in which it will be used.

No emissions data are available for this source. However, as the rubber stock is bonded to fabric, steel mesh, or glass fiber, its plasticity is maintained by steam-heating the calender rolls, typically to temperatures of 70°C to 80°C. Therefore, VOC emissions from calendering should be very similar in character and magnitude to those from milling or extrusion. Consequently, the estimated average VOC emission factor for calendering operations is 0.6 gram (0.001 lb) per tire. This value is determined for illustrative purposes only.

3.2.2.4 Bead Formation. Tire beads are rubber-covered wires which ensure a seal between a tire and the rim of the wheel on which it is mounted. In general, bead formation is accomplished by simultaneously extruding rubber onto several strands of braided copper or brass-plated steel wire and fashioning several layers of this coated wire into a ring. The rubber material may be tackified to ensure proper adhesion of the bead assembly to the sidewall when the tire is built, although not all companies follow this practice.

To facilitate tackification of the extruded rubber, the bead assembly may be dipped, sprayed, rolled, or swabbed with a solvent-based cement. Cement application can occur either before the strands are wound into a bead or after. One method of applying cement after bead formation, bead dipping, consists of manually immersing bead packages or bundles into a cement vat. The dipped packages are raised from the tank, the excess cement allowed to run off, and the beads manually racked for drying. Another dipping method consists of placing individual beads on conveyorized hooks, which are designed to dip the beads, allow excess cement to run off, and carry the beads to a drying area. Spray application of bead cement may be performed in a manner similar to package dipping of beads. Another tackification method involves manual application of solvent to the assembled bead. In some cases, a layer of rubber-coated fabric is wrapped around the bead; natural tack may be relied on for adhesion. Another cement application method incorporates the tackifying agent into the rubberized fabric wrap.[50] Where cement is applied before bead formation, the extruded rubber wire is passed across a cement-laden roller or swab suspended in a small cement trough. A bead is then fashioned out of the cemented material.

Solvents employed for bead cementing operations include: naphtha, white gasoline, hexane, heptane; some isopropanol and toluene.[1-25] Solvent evaporating from excess sprayed cement, the dip tank, roller, swab, or cement trough, and the bead material once it is removed from the cement application area constitute potential VOC emission points. Local and general ventilation methods are employed by the tire industry to maintain workplace VOC concentrations associated with bead tackification operations below OSHA employee exposure limits (Section 3.3.3). Industry-supplied data indicate that exhaust gas flow rates from bead cementing operations vary from 0.1 to 4.7 m^3/sec (212 to 9,960 scfm) and have VOC concentrations which range from 0.21 to 3.7 g/m^3 (13.1×10^{-6} to 231.0×10^{-6} lb/ft^3).[1-25] Appendix C contains emission and operating data specifically for plant bead cementing operations. Based on the application of mass-balance calculations delineated in Appendix C, a nominal 70 percent/30 percent distribution of emissions from the cement application apparatus and cemented bead, and an 8 percent absorption factor for solvent applied to the bead,[40,41] the mean VOC emission factor for all bead cementing methods is estimated to be 8.3 grams (0.018 lb) of solvent VOC per tire. This emission factor is a combined value, as average VOC emission factors for bead dipping, rolling, and swabbing differ by approximately 1 gram per tire. Bead spraying emissions are higher than bead dipping, rolling, or swabbing; however, in 1979, only one plant reported using a bead spraying operation.[15-25]

3.2.3 Tire Building

3.2.3.1 Conventional Tire Building Techniques. Passenger car and truck tires are built as cylinders on a collapsible, rotating drum. First the inner liner, which makes the finished tire airtight, is wrapped around the drum, followed by the required layers (plies) of rubber impregnated fabric. Next the edges of the fabric and inner liner are wrapped around the bead assemblies. This step is followed by a manual or automatic rolling operation (stitching) where pressure is applied from the tread centerline out to the beads in order to expel air trapped between the assembled components. Then the belts, made of fabric, steel, or glass fiber, are laid onto the cord. Finally, the tread and sidewall components are wrapped around the assembled components and are stitched. The product is an uncured or "green" tire. There are three reported variations in the method of assembling tires. In one-stage tire building, all components are assembled on one machine. Two-stage tire building consists of constructing the carcass at one site, and at a second site rechecking the subassembly, and then applying and stitching the belts, tread, and sidewall. Three-stage tire building involves carcass assembly, belt/tread construction, and final tire assembly at different stations. Single-stage construction is normally utilized to produce bias and bias-belted tires. Two- and three-stage building methods are generally employed for radial-ply tire construction.[51]

Organic solvents, such as naphtha, white gasoline, heptane, hexane, isopropanol, methanol, and toluene, may be used during building to tackify the rubberized tire components.[1-14] The purpose of tackifying rubber components is to keep the green tire intact prior to curing. Solvent may be applied when tire components have lost natural tack or if the company tire building instructions specify the use of solvent for a particular tire type. Tire builders generally are allowed considerable discretion as to whether to apply solvent.

Potential VOC emission points at tire building stations are the solvent pot, applicator brush, and tackified tire components. VOC emissions may vary between tire building machines, as the quantity of solvent used for component assembly can be directly influenced by the machine operator. Solvent use may vary for one-, two-, or three-stage tire building operations and may differ between machines used for each step of two- or three-stage tire assembly processes.

Presently, most of the tire industry uses only general ventilation to keep workplace organic vapor concentrations due to evaporation of solvents applied during tire building below OSHA employee exposure limits (Section 3.3.3). Consequently, tire building exhaust flow rates range from 3.3 to 10.6 m^3/sec (6,992 to 22,460 scfm), and VOC concentrations in the exhaust stream vary from 0.01 to 0.32 g/m^3 (0.6×10^{-6} to 20.0×10^{-6} lb/ft^3).[1-14] Based on data supplied for existing tire plants and the mass-balance calculations included in Appendix C, the average VOC emission factor for tire building is estimated to be 33.0 grams (0.073 lb) of solvent VOC per tire.

3.2.3.2 Emerging Tire Building Technology: Rotomolded Polyester Elastomer Pneumatic Tires. A new concept in tire manufacturing involves casting, rather than constructing tires. Polyair Maschinenbau GmbH has developed a liquid injection molding (LIM) system which has at its center a compact production cell or module that forms a completely self-contained tire production unit. The cast tire is produced by assembly of the core unit, mixing and injection of the liquid chemical system, setting of the tire, and tempering. The entire process can be manual, partially automated, or fully automated.[52]

When fully developed, rotomold tires are expected to offer several advantages over conventional tires: 40 percent reduction in production costs, improved uniformity, and a 25 percent reduction in weight due to lower material density. LIM tires are expected to have run-flat capabilities, thus providing greater driving safety. Energy savings are anticipated as the cast tires would be recyclable.[53,54]

Problems encountered with LIM tires are heat build-up, low coefficients of friction, and a tendency to go out-of-round. These problems have prevented the cast tire from meeting U.S. automotive specifications. One American tire manufacturer has evaluated rotomolding technology and believes the production of tires in this manner within the near future to be unlikely: production costs are not expected to decrease due to high material costs; materials needed to produce a uniform product are not available; although the urethane used to make the tires would be 10 percent less dense than rubber, no weight reduction would be achieved as the lack of strength would require that more urethane be used; the economic feasibility of recycling the tires has not been demonstrated.[37]

Even with the problems, development of tire casting methods for aircraft, trucks, and other highway vehicles has proceeded.[52-54] The

Caterpillar Tractor Company is licensing technology for filament winding closed-torus tires with detachable components.[53] Zedron, Inc., (U.S.) is preparing to market unitized tire assemblies of polyester for low-speed, off-highway use.[54] An international consortium (LIM-Holding SA) has been formed to handle LIM tire production patent rights and licensing of new technology.[52] Phoenix Gummiwerke AG is cooperating with Volkswagen to evaluate reinforced rotomolded auto tires and to obtain licensing of technology for the production of beadless tires by filament winding.[54]

3.2.4 Producing the Finished Tire

3.2.4.1 Green Tire Spraying. The green tire is removed from the tire building drum and placed, either singly or in batches, in a booth where each uncured tire is sprayed on the inside with band-ply lubricants, and on the outside with mold release agents. Band-ply lubricants reduce friction and allow air to be removed from the inside of the tire as the molding/curing bladder expands. Mold release agents prevent the outside of the tire from sticking to the mold after curing.

Solvents consumed at green tire spraying operations include naphtha, white gasoline, hexane, heptane, isopropanol, and toluene. VOC emission points due to the use of green tire sprays are solvent evaporation from the coated green tires and solvent evaporation from overspray. Materials balance calculations and evaporative rate testing have shown that approximately 80 percent of the VOC emissions originate from the application equipment; approximately 20 percent evaporates from the green tire.[47] Test results supplied by industry indicate that about 8 percent of the solvent that is applied to the green tires is absorbed.[36]

In most plants, green tire spraying is enclosed to reduce working area contamination due to overspray.[42] Where organic-based green tire sprays are used, VOC concentrations in the working area are maintained below OSHA employee exposure limits (Section 3.3.3) by venting the green tire spray booths to the atmosphere. Exhaust gas flow rates from green tire spraying booths range from 0.7 to 29.3 m^3/sec (1,270 to 62,080 scfm). VOC concentrations in the exhaust stream vary from 0.3 to 4.7 g/m^3 (21×10^{-6} to 293×10^{-6} lb/ft^3). The described organic vapor concentrations in spray booth exhaust streams may not adequately reflect total VOC emissions from green tire spraying facilities: As the enclosures were primarily designed to capture overspray, green tires may be removed from the booths before all of the solvents have evaporated. Appendix C, contains data provided by the tire manufacturing industry which pertains to the type of spray used, the number of spray booths, and exit gas properties. Based on industry-supplied solvent use data[1-25] and using the mass-balance calculations described in Appendix C, mean VOC emission factors for green tire spraying in plants using inside and outside organic solvent-based sprays are estimated to be 48.2 and 89.0 grams (0.106 and 0.196 lb) of solvent VOC per tire, respectively. Therefore, the total organic solvent-based green tire spray emission factor is estimated to be 137.2 grams (0.302 lb) of solvent VOC per tire.

Alternately, water-based sprays can be used for green tires. Approximately 82 percent of reported 1979 tire production involved the use of water-based inside sprays, and about 54 percent involved the use of water-based outside sprays.[14-25] Depending on the composition of the water-based formulation and of the organic-based formulations previously used, water-based green tire spray application can result in VOC emissions which are 95 to 100 percent less than the average organic solvent-based green tire spray emission factor.[1-25,55-69]

Water-based inside tire sprays are commercially available from several companies.[55-69] These sprays, which may contain small amounts of organic solvents, are basically aqueous dispersions of silicone solids. Specifications for water-based inside and outside tire sprays are summarized in Table 3-6. Percent composition of organic solvent in inside sprays ranges between 0 and 6 percent, by weight; outside water-based green tire spray VOC content ranges from 0 to 11 percent, by weight.[55-69] Industry-supplied information indicates that most inside and outside water-based green tire sprays have no VOCs.[14-25] Based on industry-supplied data, the average water-based inside green tire spray emission factor is estimated to be 0.1 grams (0.0002 lb) per tire; the average water-based outside

Table 3-6. COMPOSITION OF WATER-BASED INSIDE AND OUTSIDE TIRE SPRAYS

Product	Component	Amount, Percent by Weight
Inside Tire Spray	Solids[a]	20 - 60
	Water	35 - 60
	Volatile Organic Solvents	0 - 6
	Emulsifiers[b]	3 - 4
	Bactericides[c]	<1
	Corrosion Inhibitors	<1
Outside Tire Spray	Solids[b]	20 - 40
	Water	60 - 80
	Volatile Organic Solvents	0 - 11

[a] Polydimethylsiloxane, other silicone compounds, and/or mica.

[b] Composition not specified.

[c] 6-Acetoxy-2,2-dimethyl-m-dioxane.

spray emission factor is estimated to be 1.4 grams (0.003 lb) per tire. Therefore, the total average water-based green tire spray emission factor is estimated to be 1.5 grams (0.003 lb) per tire.

3.2.4.2 Molding and Curing. Passenger car tires are molded and cured in automatic presses. A rubber bladder is inflated inside the tire, causing it to assume the characteristic doughnut shape. As the bladder inflates, the mold is closed. Steam heat is applied to the outside of the tire through the mold and to the inside by the bladder. Excess rubber and trapped air are forced out through weepholes in the mold. After a time, pressure, and temperature-controlled cure, the press is cooled, the bladder is deflated, and the tire, complete with grooved tread and raised lettering, is removed from the mold. Curing usually takes 20 to 60 minutes at a temperature of 100°C to 200°C.[42] After removal from the mold, cured tires are usually inflated and allowed to cool. This last step ensures product quality and uniformity by allowing the tire to cure completely under controlled conditions.[42]

Tire curing and molding has two potential VOC emission points. The heated, VOC contaminated air may be emitted through the curing mold weepholes or as the mold opens. Based on the use of mass-balance calculations similar to those described in Appendix C, an average emission factor for molding and curing is estimated to be 2.0 grams (0.004 lb) per tire. This emission factor compares favorably to the value of 2.2 grams (0.005 lb) of VOC per tire calculated using the temperature-weight loss equation in Appendix C and the assumption that a curing temperature of 150°C is applied to an average tire mass of 11.5 kilograms. Although the emission factor and temperature-weight loss equation tend to agree, the values must be used with caution, as identification and measurement of VOC emissions from tire molding and curing operations pose a complex problem. This problem has been recognized, and a tire curing study has been undertaken by the U.S. EPA's Industrial Environmental Research Laboratories (IERL).

3.2.4.3 Finishing. After the tires have cooled, the rubber whiskers formed from excess rubber, which has cured in the weepholes of the mold, are removed by a grinding machine. Final buffing and grinding of most tire treads is performed to ensure proper balance.

The black protective strip is ground off tires which are constructed with a white sidewall strip. The white sidewalls are given a water-based protective coating to minimize scuffing during shipping or mounting on rims. Some tires may receive decals or other manufacturer markings prior to inspection and shipping. These operations may involve the use of organic solvent-based inks, paints, or sprays. Consequently, markings applied with organic solvent-based coatings constitute VOC emission points.

Volatile organic compound emission calculations for finishing operations are based on the mass-balance calculations described in Appendix C and use data provided by the tire industry.[1-14] The average VOC emission factor for tire finishing was estimated to be 5.7 grams (0.013 lb) per tire. Calculated annual VOC emissions reported for finishing operations at existing tire manufacturing plants are listed in Appendix C. Operational exhaust flow rate ranges and ranges of VOC concentration in the exhaust stream are also included.

3.2.5 Summary of VOC Emissions from Tire Manufacturing

The total uncontrolled VOC emission factor is estimated to be 308.4 grams (0.680 lb) VOC per average tire produced; this value assumes the use of organic solvent-based green tire spraying. Organic solvent-based green tire spraying, undertread cementing, sidewall cementing, tire building, tread end cementing, and bead cementing contribute 97 percent of the total VOCs emitted from tire production. Average uncontrolled VOC emission factors associated with tire manufacturing operations are summarized in Table 3-7.

3.3 EMISSIONS UNDER EXISTING REGULATIONS

3.3.1 Applicable Federal Standards and Regulations

As of January 1980, there were no Federal or State regulations governing VOC emissions from tire manufacturing plants. General hydrocarbon regulations do exist, but are not specifically applicable to VOC emissions from rubber tire manufacturing plants. Connecticut does use its general hydrocarbon regulations to reduce VOC emissions from the undertread cementing and green tire spray facilities of one plant. State Implementation Plans (SIPs) are being revised to include regulations for existing tire plants. Regulations adopted will be

Table 3-7. CALCULATION OF AVERAGE VOC EMISSION FACTORS FOR TIRE MANUFACTURING OPERATIONS[1-25]

Operation	Exhaust Flow Rate		VOC Concentration in Exhaust Gas		Average VOC Emission	
	m^3/s/Unit	(scfm)	g/m^3	(10^{-6} lb/ft^3)	Grams/Tire	(Pounds/Tire[a])
Compounding	---	---	---	---	1.0	(0.002)[b]
Milling	---	---	---	---	0.6	(0.001)[b]
Extrusion	---	---	---	---	0.6	(0.001)[b]
Undertread						
Cementing	0.6-4.4	(1,271-9,323)	0.72-5.00	(90.0-310.0)	63.2	(0.139)[c]
Sidewall						
Cementing	---	---	---	---	41.1	(0.091)[c]
Tread End						
Cementing	0.8-9.4	(1,695-19,920)	0.02-5.20	(1.2-324.6)	15.1	(0.033)[c]
Latex Dipping	---	---	---	---	---	---
Calendering	---	---	---	---	0.6	(0.001)[b]
Bead Cementing	0.1-4.7	(212-9,960)	0.21-3.70	(913.1-231.0)	8.3	(0.018)[c]
Tire Building	3.3-10.6	(6,992-22,460)	0.01-0.32	(016-20.0)	33.0	(0.073)[c]
Organic						
Solvent-based						
Green Tire						
Spraying	0.6-29.3	(1,270-82,080)	0.34-4.70	(21.0-293.0)	137.2	(0.302)[c]
Inside	---	---	---	---	48.2	(0.106)[c]
Outside	---	---	---	---	89.0	(0.196)[c]
Curing	---	---	---	---	2.0	(0.004)[c,d]
Finishing	---	---	---	---	5.7	(0.013)[c]
Total	---	---	---	---	308.4	0.680

---

[a] Based on an average tire weight 11.5 kilograms.

[b] Calculated from temperature-weight correlation in Appendix C-3.

[c] Derived from industry-supplied solvent consumption data using the calculation methodology described in Appendix C-1. The industry-supplied data were used in estimating the total average VOC emission per tire.

[d] The average VOC emission factor for curing when calculated from the temperature-weight correlation is 2.2 grams (0.005 pounds) per tire.

based upon recommendations for VOC emission reduction as outlined in the OAQPS Guidelines Series, Control of VOC Emissions from Manufacture of Pneumatic Rubber Tires (CTG).[70] Levels of control recommended as Reasonably Available Control Technology (RACT) in the CTG are presented in Table 3-8. The SIPs governing VOCs emitted from existing tire plants are expected to be submitted to EPA for consideration by July 1, 1980.[71,72] All SIPs are expected to be reviewed and approved by EPA by December 1981. Once the SIPs for existing tire plant VOC emissions are approved and promulgated, a schedule will be formulated in which each State would have 1 year to develop an enforcement program for compliance with VOC regulations. EPA expects that the installation of VOC emission reduction equipment in existing tire plants will take up to 2 years after promulgation of the SIPs. Therefore, VOC emission reduction for existing tire plants probably will not be in effect before late 1983.[73]

3.3.2 Baseline Emissions.

Year 1979 baseline VOC emissions for tire manufacturing plants in the U.S. are derived from the product of each operation's VOC emission factor, daily 1979 industry tire production (984,100 tires per day), and the average annual operating schedule (269 days per year).[1-25,27,55-69] As there are no current VOC regulations which apply directly to tire manufacturing, it is assumed that no VOC emission reduction techniques are employed unless otherwise specified. Tire industry-supplied information indicates that two plants (comprising 3 percent of total production) use VOC emission reduction systems in their undertread cementing lines;[1-25] emission reductions due to these systems are not included in baseline VOC emission calculations. Differences in VOC emissions due to the use of organic solvent-based and water-based green tire sprays are included in baseline emission calculations, as industry-supplied data indicate that 82 percent of reported 1979 tire production involved the use of inside water-based green tire sprays and 54 percent involved the use of outside water-based green tire sprays. Therefore, approximately 58,690 megagrams (64,690 tons) of VOCs were emitted from U.S. tire manufacturing plants during 1979. Table 3-9 presents the calculation of estimated 1979 VOC emissions from U.S. tire manufacturing plants.

Table 3-8. VOC EMISSION REDUCTION TECHNOLOGY RECOMMENDED IN THE CTG[70]

Affected Facility	Control Technology	Capture Efficiency[a] Percent	Efficiency Across Control Device Percent	Overall Efficiency Percent
Undertread Cementing	Carbon Adsorption	65-85	95	62-81
	or Incineration	65-85	90	59-77
Sidewall Cementing[b]	-----	-----	-----	-----
Tread-End Cementing	Carbon Adsorption	65-85	95	62-81
	or Incineration	65-85	90	59-77
Bead Dipping	Carbon Adsorption	75-85	95	71-81
	or Incineration	75-85	90	68-77
Green Tire Spraying	Water Based Coating	NA	NA	93-97[c]
	Carbon Adsorption	80-90	95	76-86
	or Incineration	80-90	90	72-81

[a] Percent capture efficiency for a retrofit will vary depending on the design and layout of the individual affected facility; minimum acceptable percent capture should be determined on an individual plant basis.

[b] Sidewall cementing emissions are not addressed by the CTG.

[c] This number depends upon the formulation.

Table 3-9. CALCULATION OF VOC EMISSIONS FROM U.S. TIRE MANUFACTURING FOR YEAR 1979[1-25,55-69]

Facility	Uncontrolled VOC Emission Factor-Grams (pounds) per tire	Daily Tire Production For the Industry During 1979	Uncontrolled VOC Emission Per Day Megagrams (tons)	Uncontrolled VOC Emissions Per Year Megagrams (tons)[f]	
Undertread Cementing	63.2 (0.139)	984,100	62.2 (68.6)	16,730	(18,442)
Sidewall Cementing	41.1 (0.091)	984,100	40.4 (44.6)	10,880	(11,993)
Tread End Cementing[a]	15.1 (0.033)	984,100	14.9 (16.4)	3,997	(4,406)
Bead Cementing	8.3 (0.018)	984,100	8.2 (9.0)	2,197	(2,422)
Green Tire Spraying					
Organic Inside Spray[b]	48.2 (0.106)	177,138	8.5 (9.4)	2,296	(2,532)
Organic Outside Spray[c]	89.0 (0.196)	452,686	40.3 (44.4)	10,841	(11,950)
Water based inside spray[d]	0.1 (0.001)	806,962	0.1 (0.1)	22	(24)
Water based outside spray[e]	1.4 (0.003)	531,414	0.7 (0.8)	20	(22)
Other	43.5 (0.096)	984,100	42.8 (47.2)	11,513	(12,691)
Total[b,c,d,e]	221.7 (0.489)	984,100	218.1 (240.4)	58,689	(64,694)

[a] Automatic and manual application method.

[b] Organic inside green tire spray used in 18 percent of tire production.

[c] Organic outside green tire spray used in 46 percent of tire production.

[d] Water-based inside green tire spray used in 82 percent of tire production.

[e] Water-based outside green tire spray used in 54 percent of tire production.

[f] Based on an average operating schedule of 269 days per year.

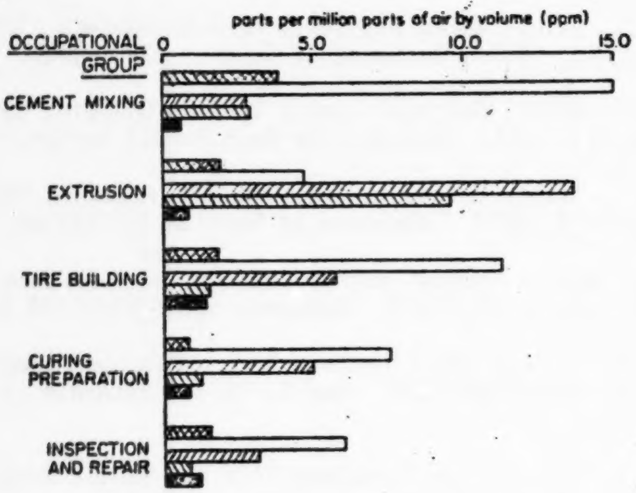
3.3.3 Applicable Occupational Safety and Health Regulations

The Occupational Safety and Health Act of 1970[74] authorizes the Secretary of Labor to set standards which will afford the highest degree of health and safety protection to the employee. Subsequently, 29 CFR Subpart Z 1910.1000 sets employee exposure limits for selected air contaminants.[75] Table 3-10 lists exposure limits for solvents generally used in tire manufacturing. An Occupational Health Study Group (OHSG) study of rubber workers funded by the United Rubber Workers, Armstrong, Firestone, General, Goodrich, Goodyear, and Uniroyal tire companies reported that working area vapor concentrations were well below the limits set in 1910.1000.[76] Figure 3-2 illustrates OHSG's observation. Existing OSHA regulations are not expected to affect baseline emission values, though it is important that any proposed VOC emission control strategy must not conflict with OSHA regulations.

Table 3-10. OSHA EXPOSURE LIMITS FOR SOLVENTS GENERALLY USED IN TIRE MANUFACTURING[75]

Substance	Employee Exposure Limit[a] ppm	mg/m^3
Heptane (n-heptane)	500	2,000
Hexane (n-hexane)	500	1,800
Isopropyl alcohol	400	980
Methyl alcohol	200	260
Naphtha	100	400
Pentane	1,000	2,950
Toluene	200	--

[a] 8-hour time weighted average



Exposure Limit Values (ppm)

▩	Pentane	600
☐	Hexane	100
▨	Heptane	400
▧	Toluene	100
■	Benzene	10

Figure 3-2. Concentrations of Organic Vapors: Median of Plant Arithmetic Averages[76]

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4.0 EMISSION CONTROL TECHNIQUES

This chapter identifies air pollution control technology that is available for reducing volatile organic compound (VOC) emissions from the following operations:

(1) undertread cementing;
(2) sidewall cementing;
(3) tread end cementing;
(4) bead cementing;
(5) green tire spraying.

Emission points for undertread and sidewall cementing operations are the cement application area and drying area conveyor. Automatic and manual tread end cementing emission points are the cement application area, the attendant drying area conveyor, and temporary storage area. VOC-emitting portions of bead cementing and green tire spraying operations include cement or solvent application areas and temporary component storage sites. Emissions from these tire manufacturing operations represent approximately 85 percent of VOCs emitted from rubber tire manufacturing plants.[1-25]

Although conventional tire building, as defined in Section 3.2.3.1, is a major VOC-emitting activity accounting for approximately 11 percent of total plant emissions, it will not be further considered in this document. Exhaust gas flow rates provided by general ventilation of the tire building work area are high (3.3 to 10.6 m^3/sec/unit [7,000 to 22,500 scfm/unit]) and contain low VOC concentrations (0.01 to 0.32 g/m^3 [0.6×10^{-6} to 20.0×10^{-6} lb/ft^3]).[1-14] Consequently, treatment of the conventional tire building exhaust stream is difficult. Technology for VOC emission reduction systems which utilizes both a capture component and a control component is available, but the cost of transferring this technology to conventional tire building, based upon the designs considered, has been determined to be very high [$98,000 to $306,000 per Mg ($90,000 to $280,000 per ton) of VOC emissions reduced] relative to the cost of regulating other facilities.[26] Tire finishing will not be considered for regulation for similar reasons: organic solvent is only used in small quantities and in open areas, resulting in very low, widely dispersed VOC emissions.

Compounding, milling, extrusion, calendering, curing, and finishing are not addressed in this chapter as emissions from these points are estimated to contribute about 3 percent to a tire plant's total VOC emissions.[1-25] Latex dipping will not be considered for control as the process is more frequently performed in textile mills (Section 3.2.2.2).

4.1 FACTORS AFFECTING EMISSION CONTROL TECHNIQUES

Methods of meeting Occupational Safety and Health Administration (OSHA) employee exposure limits for solvents used in the five operations include:

(1) dilution of air containing solvents with air from the outside atmosphere;

(2) containment and removal of solvents at their emission point;

(3) elimination or reduction of solvent use.

In order to meet fire safety codes, organic vapor concentrations in tire plant ventilation systems are diluted and maintained below 25 percent of the Lower Explosive Limit (LEL).[27] Occupational Safety and Health Administration employee exposure limits for various rubber industry related chemical compounds require maintenance of lower work area VOC concentrations than those required under fire safety codes. Therefore, large volumes of air may need to be drawn off the affected work area in order to facilitate compliance with OSHA limits. Employee exposure limits for solvents used in the rubber industry as of July 1, 1978, were presented in Tables 3-4 and 3-10.

Whether due to safety or operational factors, low VOC concentrations (in the range of 60 to 1,600 ppm) in an activity's exhaust stream limit the type of equipment that may be used for emission control. Since VOC pollutants are in the vapor state, particulate control devices, such as mechanical separators, filters, and electrostatic precipitators, cannot be used.[28] Absorption techniques may be used for VOC control,[27,29] but in operation these techniques prove deficient as they cannot satisfactorily treat low VOC concentrations without long contact times and large quantities of absorbant.[30,31] Condensation is difficult for multiple component gas streams and is especially difficult where concentrations are below 25 percent of the LEL.[32] Further, the low temperatures required for condensing some VOCs would make costs prohibitive.[32] Incineration of vapors via flaring is precluded, as the waste gas lacks sufficient heating value for combustion. Incineration may be accomplished using afterburners, which are designed to treat exhaust streams with low VOC concentrations. Adsorption systems can also be designed to control diluted VOC exhaust streams.[27,28,30]

4.2 VOC EMISSION CONTROL TECHNIQUES AVAILABLE TO THE TIRE MANUFACTURING INDUSTRY

Three general methods of VOC emission reduction are available to the rubber tire manufacturing industry:

(1) emission reduction sytems (capture and control);
(2) low solvent consumption cement application techniques;
(3) low VOC content materials.

The tire manufacturing industry presently employs means of general ventilation and vapor capture for the purpose of reducing VOC vapor concentrations below OSHA Employee Exposure Limits and 25 percent of the LEL. General ventilation (dilution ventilation) employs numerous exhaust fans to move large volumes of air, thereby diluting the concentration of contaminants released in the workroom to acceptable OSHA employee exposure levels.[33] Consequently, exhaust streams from solvent application facilities exit the ventilation system at flow rates that are too high to be treated by conventional packaged air pollution control systems.[1-14]

In order to reduce the amount of air to be treated, capture systems may be installed on individual tire manufacturing facilities to isolate and remove VOCs emitted, thereby reducing the volume of air needed to be treated. Approximately 40 percent of the VOC emission points reported by tire manufacturers are hooded. These hoods function to reduce VOC concentrations below OSHA employee exposure limits.

In two plants, enclosures surrounding undertread cement application and cement drying areas are vented to carbon adsorbers: one system is a retrofit, the other is part of the original equipment design.[1-13,34] For the purposes of this document, an exhaust gas capture or containment system used in conjunction with a VOC emission control device is referred to as a VOC emission reduction system.

Due to the small number of VOC emission control devices employed by the tire industry, VOC controls used by industries producing other rubber products [Standard Industrial Classification (SIC) Group 30] were examined: Incineration has been employed for VOC emission control in the rubber hose industry.[35-37] Hence, incineration and vapor adsorption are general exhaust gas treatment techniques which may be used by the tire manufacturing industry to control VOC emissions.

An alternate strategy may be to reduce the amount of organic solvent used by the facility through increasing the efficiency of cement or green tire spray application, or by employing cement application methods which minimize cement use. Another strategy for the reduction of organic vapor emissions is the use of cements and solvents which have low VOC contents. VOC emission reduction techniques are discussed in the following subsections.

4.2.1 Incineration of VOCs

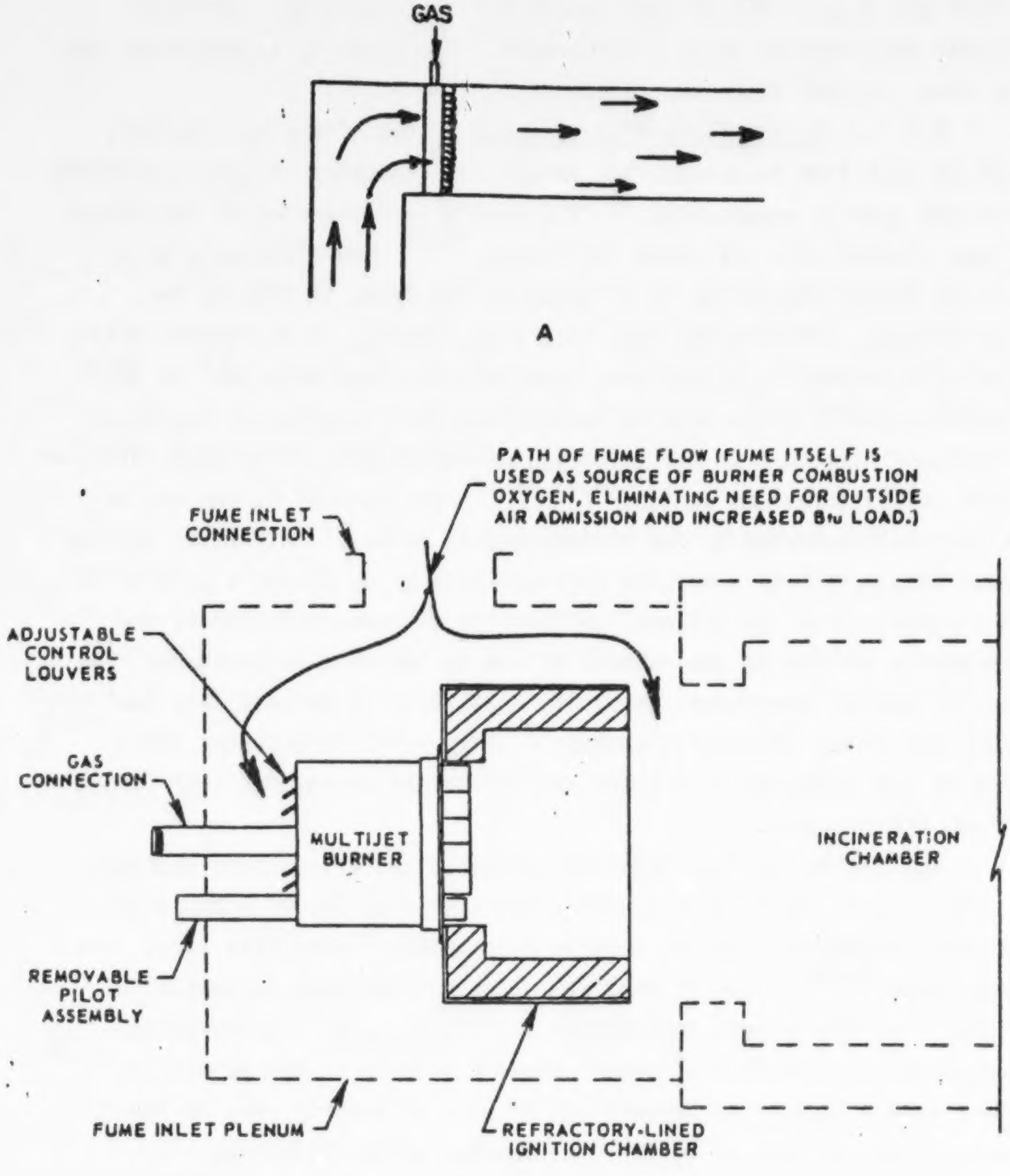
Incineration is a technique used for the control of VOC emissions by oxidizing the organic vapors into harmless products, such as carbon dioxide and water. As a result of OSHA employee exposure limits for organic vapors and fire safety consideration, VOC concentrations in the exhaust gases from solvent application facilities are low: VOC concentrations in the workplace due to OSHA regulations in many cases are below 100 ppm; fire safety codes would dictate that VOC concentrations be maintained below 25 percent of the LEL. Hence, fuel must be added to the diluted vapor before it can be incinerated. Devices which add fuel to the diluted vapors and incinerate the combined stream are referred to as afterburners. Two types of afterburners may be used: direct flame and catalytic.

4.2.1.1 Direct Flame Afterburners. Direct flame afterburners use an open fire to oxidize VOC emissions. Secondary disposal problems are not usually encountered.[38] VOC control efficiencies of new direct flame afterburners are above 98 percent.[38-44] The efficiency of a direct flame afterburner is affected by the types of VOCs to be incinerated, temperature, residence time, mixing, inlet concentration, and flow pattern. Incineration temperatures range from 455° to 980°C (850° to 1800°F); the precise temperature is a function of the vapor residence time (0.3 to 1.8 seconds), mixing chamber turbulence, effluent type, and afterburner design.[38,43,45-50] The exhaust stream may be directly incinerated by one of two general methods: either by passing exhaust gas through a burning fuel-gas jet; or by mixing a portion of the exhaust with raw gas and igniting the mixture, which heats the remaining portion of the exhaust stream to ignition temperature. The second method, premixing, generally uses 20 to 30 percent less fuel than the direct combustion method.[41] Figure 4-1 illustrates the design and operation of the two typical burner arrangements of direct flame afterburners.

Typical design flow rates for direct-flame afterburner packages range from 0.1 to 23.6 m^3/s/unit at 21°C (250 to 50,000 scfm/unit), though custom-built units, capable of handling larger flow rates, are available.[45,46] Industry-supplied data indicate that exhaust flow rates from the solvent application facilities under consideration range from 0.1 to 29.3 m^3/s/unit at 21°C (210 to 62,080 scfm/unit).[1-25] Thus direct flame afterburners can be used to control VOCs in the exhaust gas streams of rubber tire manufacturing facilities.

Several disadvantages can be identified in the use of direct flame afterburners: consumption of fuel when no VOCs are present, nitrogen oxide emissions, and emission of incomplete combustion products.

Direct flame afterburners require continuous fuel burning, although periodically, VOCs may not be present in the exhaust stream. Fuel


GAS
A
PATH OF FUME FLOW (FUME ITSELF IS USED AS SOURCE OF BURNER COMBUSTION OXYGEN, ELIMINATING NEED FOR OUTSIDE AIR ADMISSION AND INCREASED Btu LOAD.)
FUME INLET CONNECTION
ADJUSTABLE CONTROL LOUVERS
GAS CONNECTION
MULTIJET BURNER
INCINERATION CHAMBER
REMOVABLE PILOT ASSEMBLY
FUME INLET PLENUM
REFRACTORY-LINED IGNITION CHAMBER
B

A. Raw gas burner and multiple jet grid.
B. Multijet burner with exhaust gas preheater.

Figure 4-1. Typical Burner Arrangements Used in Direct Flame Afterburners[32,38,52]

requirements for direct flame afterburners are highest at 0 percent of the LEL and decrease as the VOC concentrations in the exhaust stream increase.[43] Therefore, whenever the exhaust stream contains no VOCs, fuel is wasted.[27,28,32,38,41,43,51]

Nitrogen oxide (NO_x) emissions in the afterburner exhaust may contribute to air pollution problems. Two potential sources of nitrogen can be identified: fuel-bound nitrogen and thermal fixation of nitrogen from the atmosphere. Residual fuel oil is rich in fuel-bound nitrogen and can contribute to greater than half of all NO_x being emitted from a source.[52] If the afterburners employ natural gas or distillate fuel oil for combustion, thermal nitrogen fixation is a problem.[27,52] Thermal fixation of nitrogen from the atmosphere is a function of the temperature in the combustion chamber and available oxygen.[52] Consequently, NO_x emissions in the exhaust increase as incineration temperatures and oxidation efficiencies increase.[27,39,52] Further, emission levels vary considerably with the type of unit used and the extent of loading.[52] Several combustion modifications can be employed for NO_x emission reduction:

(1) limited excess air firing can reduce NO_x emissions by 5 to 30 percent,

(2) staged combustion can reduce NO_x emissions by 20 to 45 percent, and

(3) flue gas recirculation can reduce NO_x emissions by 10 to 45 percent.

A more in-depth discussion of NO_x emission control techniques can be found in U.S. EPA's publication, Control Techniques for Nitrogen Oxide Emissions from Stationary Sources.[52]

Incomplete combustion of VOCs in the exhaust gases may create a larger nuisance than the original substance: incompletely combusted VOCs may be more potent smog precursors than the VOCs in the exhaust stream; sulfur and halogens in exhaust gases can create problems by the production of sulfur oxides and acid gases.[27] It is recommended that low-sulfur fuels, such as natural gas, distillate oil, low-sulfur residual oil or desulfurized oil, be used as afterburner fuel, although it is recognized that the availability of these resources is limited.[53]

4.2.1.2 Catalytic Afterburners. The design of catalytic afterburners is similar to direct flame types. The major difference between the types of incineration is that catalytic afterburners employ a solid, active surface on which the combustion reaction takes place. Exhaust gas is incinerated as it passes through a heated (200° to 650°C) catalyst; usually a noble metal, such as platinum or palladium, suspended in a honeycomb fashion.[28,37,38,43,45,50,54,55,56] Figure 4-2 presents the general design and operation of a catalytic afterburner.

Catalytic afterburners are reported to have VOC control efficiencies between 81 and 96 percent.[37,38,43,56,57,58] Efficiency of vapor incineration is associated with the afterburner temperature, which is in turn dependent on the vapor's ignition temperature, afterburner space velocity, and catalyst type. Typical design flow rates for catalytic afterburners range from approximately 0.2 to 18.9 m^3/s at 21°C (420 to 40,050 scfm).[32,55,56] Industry-supplied data show exhaust flow rates from VOC-emitting facilities to range from approximately 0.1 to 29.3 m^3/s/unit at 21°C (210 to 62,080 scfm/unit).[1-14] Therefore, catalytic afterburners have the potential to be employed as a VOC control component for the reduction of VOCs from rubber tire manufacturing.

Usually catalytic afterburners consume 40 to 60 percent less fuel than direct flame types, as the catalyst requires lower temperatures to bring the vapor and fuel mixture to its ignition point.[45] Catalytic afterburner fuel use is constant from 0 to 15 percent of the LEL; at 25 percent of the LEL, fuel requirements drop slightly.[43] However, as with direct flame afterburners, fuel is wasted as it is burned during periods when no VOCs are emitted.

Maintenance of catalytic afterburners is frequent. Some VOC mixtures cannot be properly incinerated, allowing particulates to foul or deactivate the catalyst.[27,29,38,55] High temperatures are known to shorten the catalyst life, thus limiting the VOC concentrations that may be treated by catalytic afterburners to 25 percent or less of the LEL.[43] Further, gas streams containing sulfur, silicon, tin, phosphorus, halogens, or heavy metals are known to poison platinum and palladium-type catalysts, thereby allowing the gas stream to pass

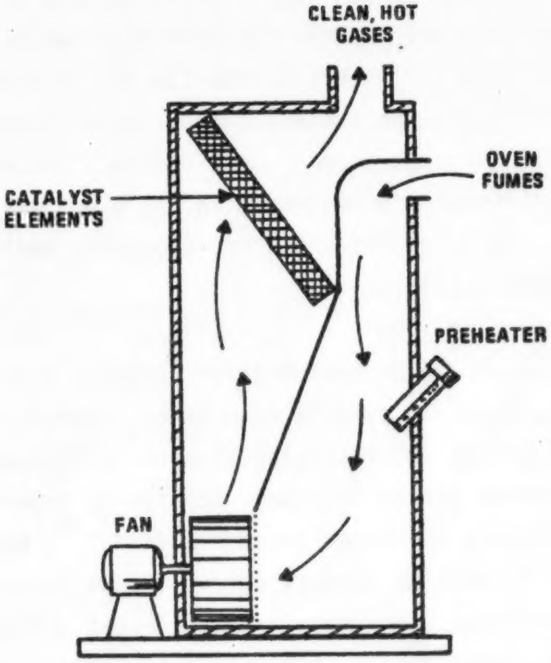

CLEAN, HOT GASES
OVEN FUMES
CATALYST ELEMENTS
PREHEATER
FAN

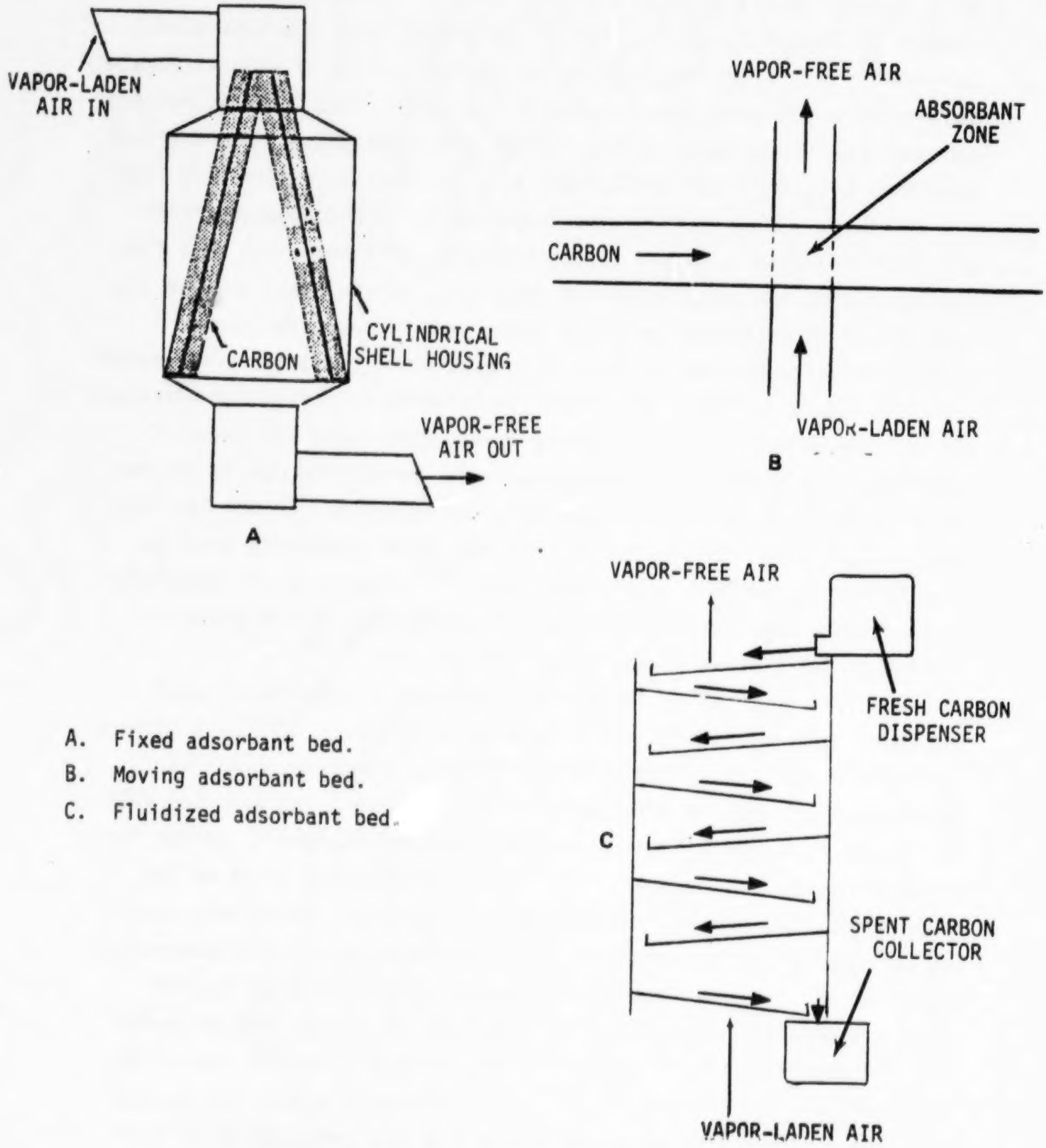
Figure 4-2. Schematic Diagram of a Catalytic Burner Using a Torch-Type Preheater. In Order to Promote Mixing, Flow of the Preheated Waste Stream is Pulled through a Fan[51]

untreated through the catalyst and become an environmental hazard.[27,32,41,45] Consequently, quality of fuel used by the catalytic afterburner is of importance.

4.2.1.3 Heat Recovery. Heat recovery offers a way to reduce the energy consumption of incinerators. The simplest method, primary heat recovery, uses the hot cleaned gases exiting the incinerator to preheat the cooler incoming gases. Depending on the design, primary heat recovery efficiencies range from 35 to 90 percent of heat input.[50,56,57] Secondary heat recovery employs incinerator exhaust from the primary heat recovery stage (or directly from the incinerator if there is no primary heat recovery) to replace energy usage elsewhere in the plant. Usual efficiencies for secondary heat recovery units are 70 to 80 percent of heat input, though circumstances in the plant may affect these values.[32,43] There is little use for secondary heat recovery in tire manufacturing plants.

4.2.2 Adsorption of VOCs

As an alternative to incineration, organic vapors may be collected on external surfaces of a solid adsorbant. Commonly used adsorbants for vapor collection are activated alumina, silica gel, and activated carbon. Activated carbon is widely applied to organic vapor collection, due to its affinity for nonpolar compounds.[27,38] Adsorption equipment collects VOCs by passing exhaust stream vapors through either fixed, moving, or fluidized beds containing activated carbon. The simplest adsorption equipment design is a vertical cylinder containing a fixed adsorbant bed sandwiched between screens. A moving bed configuration passes activated carbon through an adsorption zone. In fluidized bed adsorbers, vapors are forced upward through a stack of beds or trays, thus imparting a fluid appearance to the adsorbant. Fresh adsorbant is fed onto the tray furthest from the vapor stream inlet, flows across the bed, over a weir, and drops to the tray directly beneath. The same procedure occurs with each tray in the stack. The effect of a fluidized bed configuration is that the VOC load in the adsorbant increases as the adsorbant progresses down the tray stack. Figure 4-3 illustrates the three different methods for organic vapor adsorption.


VAPOR-LADEN AIR IN
CARBON
CYLINDRICAL SHELL HOUSING
VAPOR-FREE AIR OUT
A
VAPOR-FREE AIR
ABSORBANT ZONE
CARBON
VAPOR-LADEN AIR
B
VAPOR-FREE AIR
FRESH CARBON DISPENSER
C
SPENT CARBON COLLECTOR
VAPOR-LADEN AIR

A. Fixed adsorbant bed.
B. Moving adsorbant bed.
C. Fluidized adsorbant bed.

Figure 4-3. Three Carbon Adsorption Methods[27,32,65-67]

Fixed bed carbon absorbers are reported to be able to continuously reduce VOC emissions by 95 percent; peak emission reduction efficiencies of 99 percent have also been reported.[41,59-63] Carbon absorbers are capable of treating organic vapor concentrations that are less than 100 ppm.[27,63-68] Control efficiencies are a function of vapor-activated carbon surface contact area (including bed depth, width, configuration) and humidity in the vapor stream. Fixed bed, cone-shaped, and vertical adsorbers allow more surface contact area for organic vapors than flat bed adsorbers: This enables cone-shaped units to accommodate higher air flows and lower pressure drops than would be experienced in a flat bed using the same total weight of adsorbant. Moving beds may use the same amount of activated carbon as fixed beds but may have higher control efficiencies due to fresh adsorbant being continually introduced into the adsorbing zone. The effective lifetime of moving bed adsorbers can be shorter due to wear on moving parts, more rapid attrition of adsorbant, and higher steam requirements for desorption due to shorter carbon beds.[58] Fluidized-bed absorbers can tolerate high VOC loading, require less steam for desorption, and may avoid channeling problems occasionally encountered with fixed beds.[38,51] Humidity can adversely affect carbon adsorption collection efficiency when the moisture content of the exhaust stream exceeds 50 percent.[32,33,]

Adsorber units allow for either treatment or disposal of used adsorbant material. Units which facilitate adsorbant treatment (desorption) are classified as regenerative systems. Spent adsorbant is reactivated by removing adsorbed VOCs via steaming. The desorbed VOCs are recovered by distillation or water treatment equipment, either for reuse or disposal by incineration.[58] Adsorption units which do not reuse spent adsorbant are non-regenerative systems. Spent adsorbant may be shipped out for regeneration or incineration. For a continuous, regenerative, fixed bed adsorption system, at least two adsorption tanks are needed. If the time for regeneration and cooling is longer than the adsorption time, three beds may be used: one bed adsorbing, one desorbing, and one cooling.[58] When the adsorbing bed reaches the point where higher boiling point vapors displace compounds with lower boiling points, the bed which has been desorbed and cooled is put on stream, and the VOC-laden adsorbant is steamed. In cases of solvents with high boiling points, superheated steam may be required for desorption.[38,58] After desorption, the activated carbon must be adequately cooled before it can again be placed on stream: Contact of VOCs with the heated bed may cause partial decomposition of the vapor, releasing odorous and irritating gases into the atmosphere.[38]

Carbon adsorbers have an advantage over afterburners since they can remove low VOC concentrations (less than 100 ppm) from exhaust streams, even in the presence of water vapor.[27,39,63-67] However, under conditions of low VOC concentrations, carbon adsorption efficiencies decline. Unlike afterburners, VOCs that are adsorbed may be recovered from desorption steam and reused.

There are, however, certain disadvantages associated wit carbon adsorbers. Any particulate matter in the exhaust stream may plug the carbon beds, lowering their VOC collection efficiencies. Also, the required depth of a carbon bed increases with the number of compounds in the exhaust stream.[51] Thus, even if the VOC concentrations in two exhaust streams are similar, the carbon bed depths required may be very different if one exhaust stream contains several compounds while the other contains only one. Further, VOCs are adsorbed in an inverse relation to compound volatilities, with highly volatile compounds adsorbed first.[30] As a result, the composition of reclaimed materials may differ greatly from the virgin material, possibly precluding its reuse in a tire manufacturing activity.

Typical design flow rates for carbon adsorption package units range from less than 0.05 m^3/s to 37.76 m^3/s at 21°C (100 scfm to 80,000 scfm).[58,65-68] Exhaust flow rate data from the tire industry indicate a potential for application of carbon adsorption to VOC emission points, as flow rates range from approximately 0.1 to 29.3 m^3/s/unit at 21°C (210 to 62,000 scfm/unit).[1-14] One retrofit carbon adsorber is currently employed on the undertread cementing line at one tire manufacturing plant. Tests performed on this carbon adsorber indicate that the device has an average continuous VOC removal efficiency of 90 to 95 percent;[63] factors constraining higher removal efficiencies are outlined in Section 4.3.1. Further, carbon adsorbers used to control VOC emissions from other rubber products and pressure sensitive tapes/labels manufacturing have been reported to have continuous control efficiencies of at least 95 percent.[60-62]

4.2.3 Low Solvent Consumption Cement Application Activities

An alternative to the use of add-on emission reduction systems is to increase the effectiveness of cement or solvent application to the rubber component, thereby reducing the amount of cement or solvent used. Consequently, VOC emissions are lower than similar, less effective application operations. Industry-supplied information indicates that at least one tread end cementing operation and one bead cementing operation from each reporting company consumes such low amounts of cement that VOC emissions are equal to or less than 10 grams per tire.[1-25] These low solvent consuming cement application activities are further discussed in Sections 4.3.3 and 4.3.4.

4.2.4 Low VOC Content Materials

An alternative strategy for reducing VOC emissions is to substitute lower VOC content materials for materials with higher VOC contents. Water-based inside and outside green tire sprays are currently the only well developed low-VOC content materials available to the tire manufacturing industry.[1-25] Overall emission reductions resulting from tire application of inside and outside water-based green tire sprays range approximately 90 to 100 percent of the average organic solvent-based emission factors for inside and outside green tire sprays[69-83]; the extent of the emission reduction is dependent on the VOC content of the sprays used and the amounts applied. Further discussion of water-based green tire sprays is included in Section 3.2.4.

4.3 APPLICATIONS OF VOC EMISSION REDUCTION TECHNOLOGY

4.3.1 VOC Emission Reduction Systems for Undertread Cementing

Carbon adsorption is the only type of VOC control component currently used in the tire manufacturing industry. A dual bed carbon adsorber is part of a retrofit VOC emission reduction system at one plant's undertread cementing operation; the system was installed in order to help the plant meet State regulations.[1] A second plant, which recently began production, has an enclosure and carbon adsorption unit incorporated into the original equipment of the undertread cementing line design.[34] The retrofit VOC emission reduction system consists of a 2.6 m^3/sec at 21°C (5500 scfm) enclosure connected to a standard dual-bed carbon adsorber;[49] the adsorber could be interchanged with a direct flame or catalytic incinerator.[68] The retrofit enclosure, as depicted in Figure 4-4, was designed to maintain VOC vapors at a concentration less than 25 percent of the LEL, while capturing solvent that evaporates from the cement applicator assembly and cemented tread stock.[66,84] This enclosure design can only be applied in cases where workers are not exposed to the organic vapors.[33]

Pertinent design considerations for the retrofit emission reduction system or any new undertread cementing VOC emission reduction system include:

(1) maintenance of OSHA employee exposure limits where workers are exposed to organic vapors and maintenance of VOC concentrations at 25 percent or less of the LEL where workers are not exposed;

(2) operator accessibility to areas within the enclosure for tread changes and scheduled maintenance;

(3) sufficient tread residence time in the enclosed conveyor to ensure solvent capture during drying.

The capture system can be constructed to enclose the undertread cement tank/application area and some or all of the conveyors leading away from the undertread cementing station. The enclosure requirements vary depending on the amount of VOC that is previously captured in the tank/application area, the speed of the conveyor, the rate of organic solvent evaporation, and the amount of solvent that is absorbed in the rubber. In practice, information on the rate of organic solvent evaporation could be used to determine the point on the conveyor where the concentration of VOCs in the ambient air would be so low that additional enclosure would not be practical for capturing these VOCs.

Tests performed to determine the capture efficiency of the retrofitted undertread cement tank/application area enclosure and the attendant drying area enclosure have yielded mostly inconclusive results. However, in one case, long-term materials balance measurements provided by the owner show that the retrofit capture and control

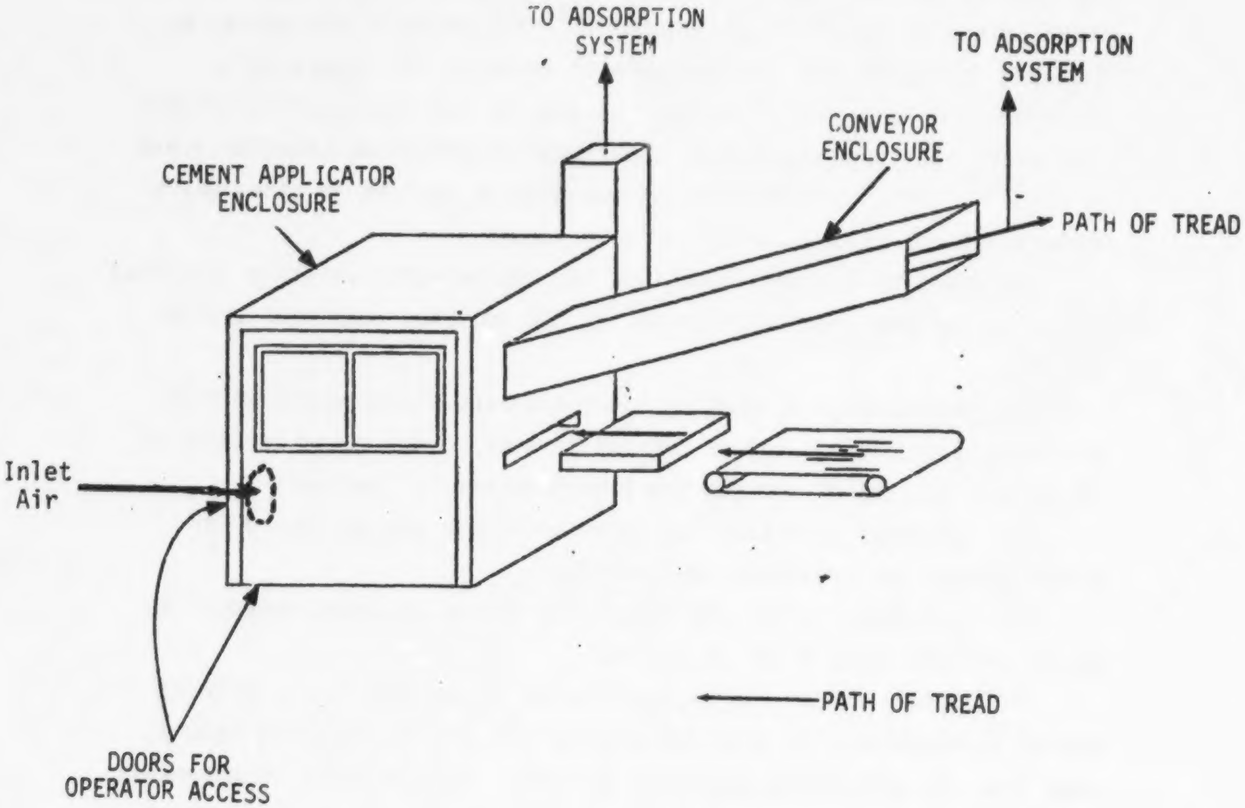

TO ADSORPTION SYSTEM
TO ADSORPTION SYSTEM
CONVEYOR ENCLOSURE
CEMENT APPLICATOR ENCLOSURE
PATH OF TREAD
Inlet Air
PATH OF TREAD
DOORS FOR OPERATOR ACCESS

Figure 4-4. Ventilation Enclosure for an Undertread or Sidewall Cementing Operation[48]

systems achieved an overall emission reduction efficiency of about 63 percent.[65] Source testing of the retrofit carbon adsorber servicing the undertread cementing capture component shows the control component to have an average VOC control efficiency of 90 to 95 percent.[63] Thus the quotient of the overall emission reduction efficiency and the carbon adsorber efficiency yields a crude capture efficiency between 66 and 70 percent. The tire company believed that the following factors limited the degree of VOC emission reduction efficiency:

(1) Approximately 8 percent of VOC applied to rubber component is absorbed by the rubber and is not immediately available for capture (emissions from cemented rubber account for about 30 percent of total VOC emissions from this line, thus, about 2.4 percent of VOC used is absorbed);

(2) Enclosure system access doors are open for a finite time span for periodic threading of new tread sizes; and

(3) Length of the drying area conveyor and enclosure is limited by the configuration of existing extrusion equipment;

(4) The switching damper installed for enclosure emergency situations is not equipped with vapor loss seals, thereby allowing a negative pressure to exist on both sides of the damper;

(5) Operating practices do not provide for containment of VOC emissions during weekend shutdown, either by draining cement tanks or by equipping tanks with tight fitting covers;

(6) Operating practices do not provide for air drying and cooling of the desorbed carbon bed prior to the next adsorption cycle;

(7) The company can not account for vapor losses from cement mixing churns, recirculating cement distribution system storage tanks, recovered solvent storage tanks, pumping, and venting from decanter.[85]

EPA analysis indicates that the design of the retrofit VOC emission reduction system can be improved, thereby increasing system efficiency to at least 75 percent on a continuous basis. New capture systems could be designed to minimize VOC loss during periods when access doors are open by providing openings which are of sufficient size to allow unhampered worker access while maintaining adequate air velocities across the face of the openings for containment of emitted VOCs. Enclosures on drying conveyors at many plants could be extended to contain more of the VOCs emitted from the cemented rubber; the length of conveyor that is enclosed would depend upon conveyor speed and the solvent evaporation rate. Vapor loss seals can be employed on dampers to improve emission reduction system efficiency. Cement tanks for the applicator assembly can be covered or drained when not in use. Carbon adsorbers employed in the system would require designs that allow proper cooling of desorbed beds before being returned to the adsorption cycle.

In addition, the EPA document, Control of Volatile Organic Emissions from Manufacture of Pneumatic Tires (CTG),[26] presents values based on capture and control technologies used in other industries. These values indicate that retrofit capture components of undertread cementing VOC emission reduction systems may be 65 to 85 percent efficient; it is expected that most systems would achieve at least 75 percent efficiency. EPA analysis indicates that capture systems for new, modified, or reconstructed operations should be able to continuously achieve at least 80 percent efficiency. Eighty-five percent capture is not considered achievable in all situations because of variation in undertread cement application equipment configuration, need for operator access, and chemical characteristics of the cements and solvents. Control components can achieve efficiencies of 95 percent. Therefore, new, modified, and reconstructed undertread cementing operations that employ VOC emission reduction systems should be able to continuously reduce VOC emissions by at least 75 percent.

4.3.2 VOC Emission Reduction Systems for Sidewall Cementing

Since the type of equipment used to apply cement to sidewall is similar to that used for undertread cementing, VOC emission reduction methods should be similar. Figure 4-4 illustrates the type of ventilation enclosure that can be used on a sidewall cementing unit.

The capture design should address the following considerations:

1. Maintenance of OSHA employee exposure limits for organic vapors in cases where workers are exposed to VOCs and maintenance of organic vapor concentrations at 25 percent or less of the LEL where workers are not exposed;

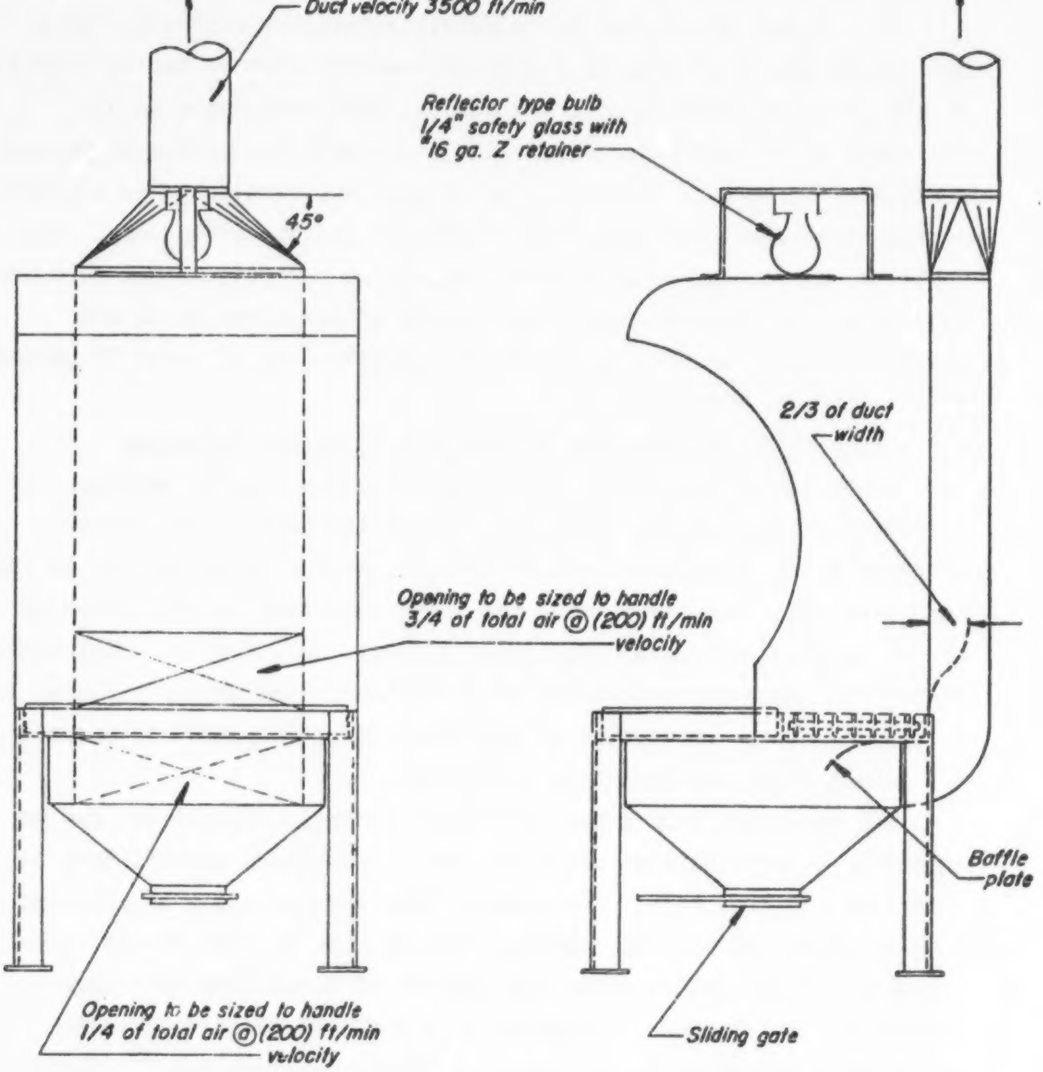
2. Operator accessibility to areas within the enclosure;

3. Retention of cemented sidewall within the enclosure for a sufficient amount of time to ensure optimum VOC capture during drying. As explained for undertread cementing, capture components on new, modified, or reconstructed lines can be designed to achieve 80 percent efficiency or better. As indicated in previous sections, new control devices are capable of attaining 95 percent control efficiency. New, modified, or reconstructed sidewall cementing operations that incorporate VOC capture and control components having efficiencies of 80 and 95 percent would be able to reduce VOC emissions by at least 75 percent on a continuous basis.

4.3.3 VOC Emission Reduction Systems for Tread End Cementing

Important parameters of any tread end cementing-VOC emission reduction system include provisions for maintenance of VOC concentrations at 25 percent or less of the LEL, worker accessibility to the cementing area, and sufficient tread residence time in the system to ensure solvent capture during cement drying. In addition, maintenance of organic vapor concentrations below OSHA employee exposure limits is a requirement for the design of any VOC capture component to be utilized for manual tread end cementing facilities.

VOC emissions from manual tread end cementing facilities can be caught by a modified side draft or slot capture hood mounted upon an underflow capture table. The capture hood and table can be enclosed on both sides and the top, thereby leaving working area access unrestricted. Such capture units are similar to those used for other industrial applications. Diagrams of a portable chipping/grinding table and a soldering table appear as Figures 4-5 and 4-6.[86] Modification of these capture units to accommodate a conveyor belt should pose little problem. Openings cut through the extended sides of the hooding to accommodate conveyors can be designed to minimize pressure losses or changes in air flow distribution that might be caused by such modifications. Drying conveyors should also be enclosed to capture solvent that is emitted from the coated tread ends. The overall efficiency of the capture system will be dependent on the extent of solvent evaporation occurring in the conveyor enclosure.


Duct velocity 3500 ft/min
45°
Reflector type bulb
1/4" safety glass with
#16 ga. Z retainer
2/3 of duct
width
Opening to be sized to handle
3/4 of total air @ (200) ft/min
velocity
Baffle
plate
Opening to be sized to handle
1/4 of total air @ (200) ft/min
velocity
Sliding gate

A. FRONT VIEW

B. SIDE VIEW

Figure 4-5. Capture System for Portable Chipping and Grinding Tables[86]

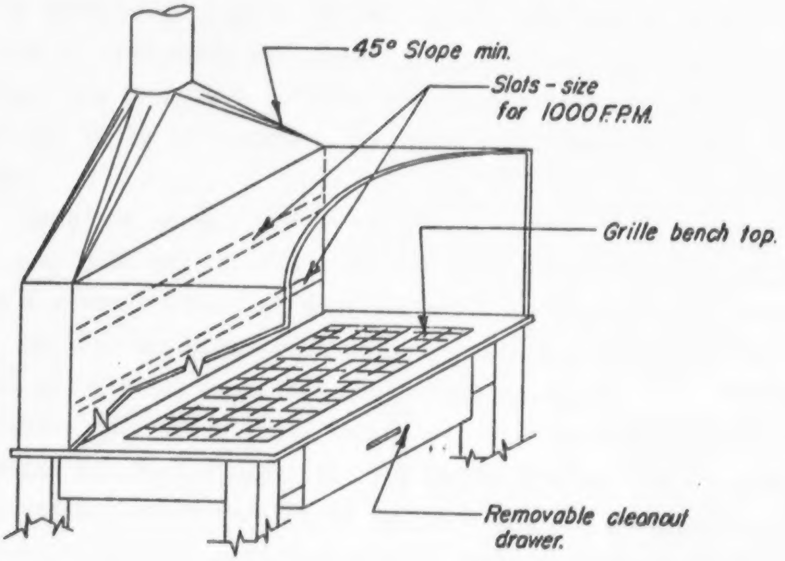

45° Slope min.
Slots - size for 1000 F.P.M.
Grille bench top.
Removable cleanout drawer.

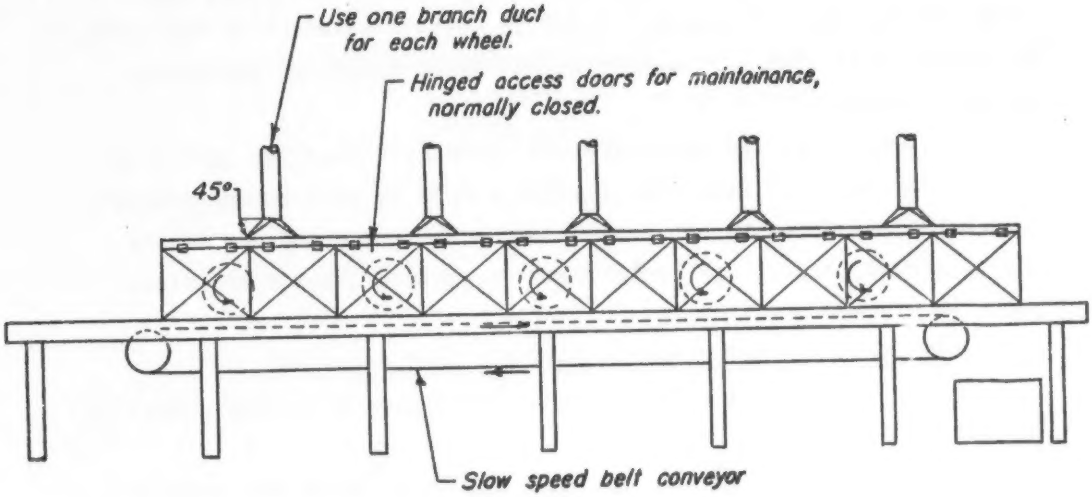
Figure 4-6. Capture System for a Soldering Table [86]

Conveyor enclosure ends should be fitted with flexible flaps to minimize dispersion of VOCs from the tread end cementing area.

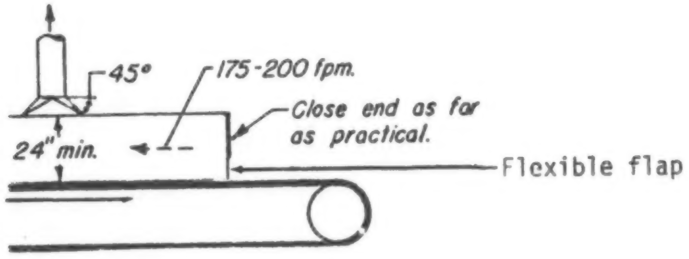
Estimates presented in the CTG,[26] indicate that retrofit capture components of manual tread end cementing VOC emission reduction systems may be 65 to 85 percent efficienct; it is expected that most systems would achieve at least 75 percent efficiency. EPA analysis indicates that capture systems for new, modified, or reconstructed operations should be able to continuously achieve 80 percent efficiency or better. Eighty-five percent capture is not considered achievable in all situations because of variations in tread end cementing equipment configuration, need for operator access, and chemical characteristics of the cements and solvents.

Automatic tread end cementing operations can be enclosed. Movable panels can be provided to allow worker access to the machinery for adjustment and maintenance. One possible enclosure type is a modification of the design used for straight line automatic buffing (Figure 4-7).[86] Drying conveyors should also be enclosed to capture solvent that is emitted from the coated tread ends. The overall efficiency of the capture system will be dependent on the extent to which the conveyors are enclosed and is related to the percentage of total solvent evaporation that occurs under the attendant conveyor hooding. Ends of the drying conveyor enclosures should be covered with flexible flaps to minimize dispersion of VOCs from tread end cementing facilities.

The CTG estimates that[26] retrofit capture components of automatic tread end cementing VOC emission reduction systems may achieve 65 to 85 percent efficiency; most capture systems are expected to achieve about 75 percent efficiency. EPA analysis indicates that capture systems for new, modified, or reconstructed operations should be able to continuously achieve at least 80 percent efficiency. Eighty-five percent capture efficiency is not considered achievable in all situations because of variations in undertread cement application equipment configuration, need for operator access, and chemical characteristics of the cements and solvents.


Use one branch duct for each wheel.
Hinged access doors for maintainance, normally closed.
45°
Slow speed belt conveyor

A. Overall View


45°
175-200 fpm.
Close end as far as practical.
24" min.
Flexible flap

B. Enclosure of Conveyor Hood Ends by Cloth Flaps

Figure 4-7. Capture System for Straight Line Automatic Buffing [86]

Alternately, low levels of VOC emissions from tread end cementing may be achieved without the aid of add-on VOC capture and control components. Industry-supplied information indicates that the small amounts of solvent used at many tread end cementing operations result in VOC emission rates which are below 10 grams (0.022 lb) per tire.[1-25,83,84] VOC emissions from some tread end cementing operations are as low as 2.0 grams (0.004 lb) per tire, which is approximately 85 percent less than the average uncontrolled tread end cementing emission factor.

New, modified, and reconstructed tread end cementing operations that employ emission reduction systems should be able to continuously reduce VOC emissions by at least 75 percent. Tread end operations employing low solvent use techniques can achieve average emissions below 10.0 grams per tire.

4.3.4 VOC Emission Reduction Systems for Bead Cementing

Several features are important to the design of a bead cementing VOC emission control system:

(1) maintenance of OSHA employee exposure limits for organic vapors where workers are exposed to VOCs and maintenance of organic vapor concentrations at 25 percent or less of the LEL where workers are not exposed;

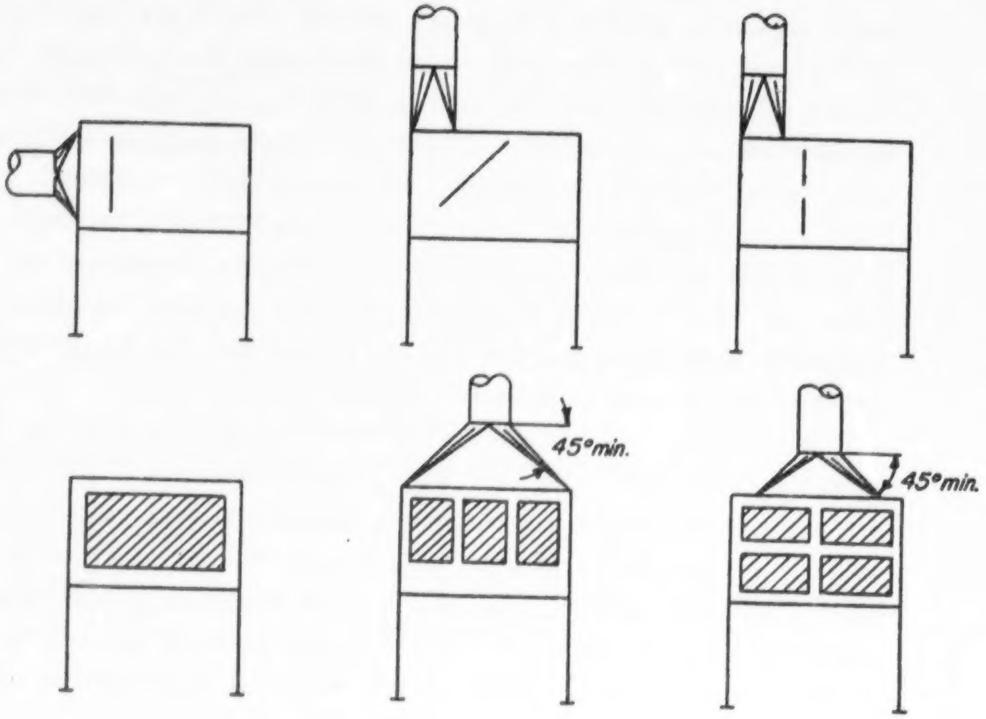
(2) worker accessibility to the bead cementing facility;

(3) sufficient residence time in the VOC capture component to ensure optimal solvent capture during cement or solvent drying.

Bead spraying, rolling and swabbing, and dipping require different VOC capture methods. These methods are described below.

4.3.4.1 Spraying. Solvent emissions from bead spraying can be reduced by controlling the quantity of cement applied and by employment of VOC emission reduction systems. Booths, similar to those shown in Figure 4-8, could be used to enclose the spraying equipment.[86] Spray booth capture efficiencies can range around 80 to 90 percent, depending on the extent of enclosure and length of time the tire component is retained in the booth.[26]

4.3.4.2 Rolling and Swabbing. Approximately 60 percent of tire manufacturing plants performing bead cementing in 1979 were using



A. Solid Baffle

B. Angular Baffle

C. Split Baffle or Filters

Figure 4-8. Capture Systems for Small Spray Booths [86]

roller or swab techniques. VOC emissions from roller or swab application can be reduced through emission reduction systems. The cement trough, roller, or swab application areas could be enclosed. VOCs emitted would be vented through a hose to a low air flow (less than 4.72×10^{-2} m^3/sec [100 scfm]) carbon absorption canister. Estimates presented in the CTG indicate that the average efficiency of VOC emission reduction systems installed on roller- or swab-type bead cementing operations would be at least 75 percent on a continuous basis.[26] However, such a system may be impractical since it would significantly increase air flow through the small application area, thereby increasing VOC evaporation rates and solvent requirements. Engineering judgment indicates that flash-off areas could not practically be enclosed due to the arrangement and location of bead forming equipment.

Many roller bead cement applicators emit small quantities of VOC, as solvent consumption is less than 10 grams per tire.[1-25,87,88] At one plant, VOC emissions from roller application were calculated through a materials balance to be 1.2 grams VOC per tire, which is approximately 85 percent less than the average uncontrolled bead cementing emission factor.[1-25,87,88] These calculations are described in Appendix C. Similar levels of VOC emissions from swabbing have not been demonstrated.

4.3.4.3 Dipping. A unit similar to the dip tank illustrated in Figure 4-9 may be useful in controlling VOCs from bead dipping operations. The dip tank's capture component consists of two slotted side draft capture hoods: one for the dip tank and one for the drainboard. The critical area of VOC emission control in bead dipping is solvent evaporation off the agitated cement and coated beads as they are removed from the dip tank. VOC capture can be augmented by equipping the dip tank hooding with extended skirts, though enclosure of the tank would result in higher capture efficiencies. A capture unit with design features similar to those presented in Figure 4-9 would be considered less efficient than total enclosure of the bead cement tank and drying area, but would afford less restricted worker access.

Estimates presented in the CTG[26] indicate that retrofit capture components for bead dipping VOC emission reduction systems may be 75

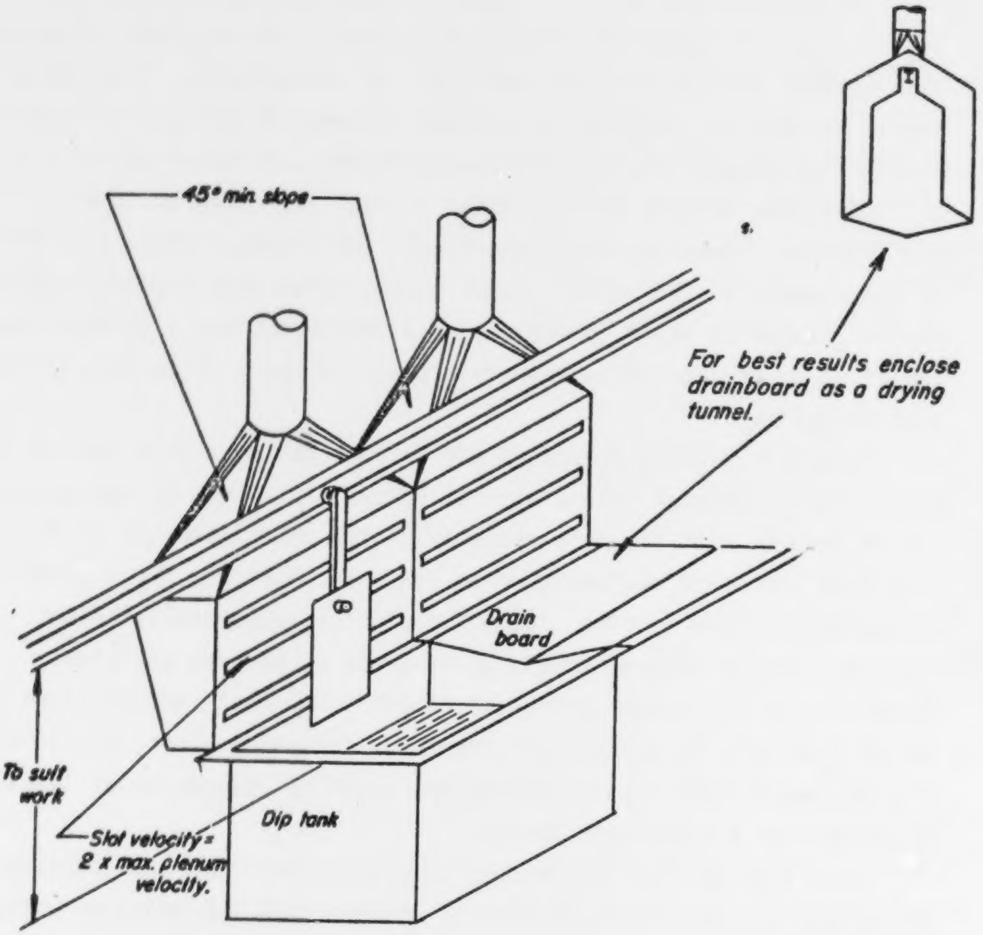

45° min. slope
For best results enclose drainboard as a drying tunnel.
Drain board
To suit work
Dip tank
Slot velocity = 2 x max. plenum velocity.

Figure 4-9. Capture System for a Dip Tank[86]

to 85 percent efficient; it is expected that most capture systems would achieve at least 80 percent efficiency. EPA analysis indicates that capture systems for new, modified, or reconstructed operations should be able to continuously achieve at least 80 percent efficiency. Eighty-five percent capture efficiency is not considered achievable in all situations because of variations in bead cementing equipment configuration, need for operator access, and chemical characteristics of the cements and solvents. Thus, uncontrolled bead dipping emissions can be reduced at least 75 percent on a continuous basis through the use of an 85 percent efficient capture system and a 95 percent efficient control device.[15,25]

Automatic dipping conveyors can be enclosed by a unit similar to the capture component illustrated in Figure 4-7. Ends of the enclosures can be covered with flexible flaps to reduce the dispersion of VOCs from bead cementing equipment. For reasons similar to those given for non-automatic bead dipping, automatic dipping equipment/attendant conveyor-line enclosures should be at least 80 percent efficient. Therefore, if 80 percent efficient capture components are employed in conjunction with 95 percent efficient VOC control devices, VOC emissions from automatic bead dipping operations could be reduced by at least 75 percent on a continuous basis.

Industry-supplied information indicates that some bead dipping operations use such small amounts of solvent that VOC emission rates below 10 grams (0.022 lb) per tire can be achieved.[1-25,87,88] In certain cases, solvent use is so low that bead dipping operations emit approximately 1.0 gram (0.002 lb) of VOC per tire: an emission rate which is about 85 percent less than the average uncontrolled emission factor.[1-25,87,88]

4.3.5 VOC Emission Reduction Techniques for Green Tire Spraying

VOC emissions from green tire spraying may be reduced by either of two techniques: substitution of water-based sprays, or use of emission reduction systems.

4.3.5.1 Materials Substitution. The use of water-based green tire sprays can reduce average organic solvent-based inside green tire spray emissions by 95 to 100 percent and average organic solvent-based outside sprays by 90 to 100 percent.[1-25,69-74] The extent of emission reduction is dependent on the formulation and amount of sprays used. It is estimated that VOC emissions from both inside and outside water-based sprays would be approximately 90 to 100 percent less than average VOC emission levels resulting from the use of both inside and outside organic-solvent based sprays.

4.3.5.2 Emission Reduction System. Neither carbon adsorbers nor afterburners have been employed by the industry as VOC control components, even though green tire spray booths (spray enclosures) can be vented to a retrofit VOC control unit. The design of a green tire spray booth is illustrated in Figure 4-8. Estimates presented in the CTG[26] indicate that retrofit capture components of green tire spraying VOC emission reduction systems may be 80 to 90 percent efficient; most plants would be expected to achieve about 80 percent efficiency. EPA analysis indicates that capture systems for new, modified, or reconstructed operations should be able to achieve 80 percent efficiency or better on a continuous basis. Ninety percent capture efficiency is not considered achievable in all situations because of variations in green tire spraying equipment configuration, need for operator access, and chemical characteristics of the cements and solvents. The length of time the coated tire is allowed to dry in the enclosure will also affect the capture efficiency.[66]

The application and effectiveness of an adsorber as a VOC control component for green tire spraying might be limited by solids in the sprays which, when suspended in exhaust stream gases, could foul the carbon beds; particulates in the capture component exhaust stream could also plug catalytic afterburners. Pretreatment of the exhaust gas by mechanical separators, scrubbers, or bag filters should eliminate this problem.[28,51,89] If 95 percent efficient carbon absorbers or afterburners are used in conjunction with 80 percent efficient green tire spray booths, VOC emissions from green tire spraying operations could be reduced by at least 75 percent on a continuous basis.

4.3.6 Summary

Table 4-1 presents emission reductions achievable using available capture and control emission reduction techniques. Information is

Table 4-1. ESTIMATED VOC EMISSION REDUCTION EFFICIENCIES USING AVAILABLE EMISSION REDUCTION TECHNIQUES[1-25,38,39,46-49,55,62-83,87,88]

	VOC CAPTURE COMPONENT	VOC CONTROL COMPONENT	VOC EMISSION REDUCTION SYSTEM
Activity	System Efficiency (Percent)	VOC Emission Control Technique[a]	Reduction Efficiency (Percent)
Undertread Cementing	80	Carbon Adsorption or Incineration	75
Sidewall Cementing	80	Carbon Adsorption or Incineration	75
Automatic Tread End Cementing	80	Carbon Adsorption or Incineration	75
Manual Tread End Cementing	80[b]	Carbon Adsorption or Incineration	75
Bead Cementing	80[b]	Carbon Adsorption or Incineration	75
Green Tire Spraying	80[c]	Carbon Adsorption or Incineration	75

[a] The control system efficiency in each case is 95 percent. Control components are not applicable for water-based green tire spraying; also not applicable for tread end cementing and bead cement operations which emit 10 grams or less VOC per tire produced (low solvent use techniques).

[b] VOC emissions from low solvent use techniques can be as much as 85 percent less than the average uncontrolled tread end cementing VOC emission factor and 85 percent less than the average uncontrolled bead cementing emission factor.

[c] VOC emissions from the use of water-based inside green tire sprays are 95 to 100 percent less than the average organic solvent-based inside green tire spray emission factor; VOC emissions from water-based outside sprays are about 90 to 100 percent less than the average organic solvent-based outside green tire spray emission factor. Thus, total VOC emissions from water-based green tire spray use are 90 to 100 percent less than the average overall organic solvent-based spray emission factor.

provided for undertread cementing, sidewall cementing, tread end cementing, bead cementing, and green tire spraying operations. EPA analysis indicates that capture/control systems installed on these operations would be able to reduce VOC emissions by at least 75 percent on a continuous basis. Water-based green tire spraying, tread-end cementing which employs low solvent use techniques, and bead cementing which employs low solvent use techniques involves reduced organic solvent consumption. Consequently, VOC emissions may be so small that further emission reduction through the use of capture/control systems may not be warranted.

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5.0 MODIFICATION AND RECONSTRUCTION

5.1 BACKGROUND

Emission limitation standards promulgated under Section 111(b) of the Clean Air Act apply to all facilities within the regulated source category that are constructed, modified, or reconstructed after the date of proposal of the standards. Uncertainties may arise as to the determination of whether any existing facility has been "modified" or "reconstructed." These issues are addressed in Sections 60.14 and 60.15, respectively, of Title 40 of the Code of Federal Regulations, which defines conditions under which an "existing facility" may become subject to standards of performance.[1,2] An "existing facility," defined in 40 CFR 60.2(aa), is an apparatus of the type for which a standard of performance is promulgated and the construction or modification of which was commenced prior to the date of proposal of that standard.

The following discussion examines the applicability of the modification/reconstruction provisions to any facilities for undertread cementing, sidewall cementing, tread end cementing, bead cementing, and green tire spraying in an existing rubber tire manufacturing plant and details conditions under which existing facilities could become subject to standards of performance for new stationary sources. The enforcement division of the appropriate EPA regional office should be contacted regarding any questions on modification or reconstruction applicability.

5.2 40 CFR PART 60 PROVISIONS FOR MODIFICATION AND RECONSTRUCTION

5.2.1 §60.14 Modification

§60.14 states:

> ". . . any physical or operational change to an existing facility which results in an increase in the emission rate to the atmosphere of any pollutant to which a standard applies shall be

considered a modification within the meaning of Section 111 of the Act. Upon modification, an existing facility shall become an affected facility for each pollutant to which a standard applies and for which there is an increase in the emission rate to the atmosphere."[1]

Paragraph (e) lists certain physical or operational changes which by themselves are not considered modifications. These changes include:

a. Facility maintenance, repair, and replacement which are determined by the Administrator to be routine.

b. An increase in the production rate not requiring a capital expenditure as defined in §60.2(bb).

c. An increase in the hours of operation.

d. Use of an alternative fuel or raw material if prior to the standard, the existing facility was designed to accommodate that alternate fuel or raw material. (Conversion to coal, as specified in §111(a)(8) of the Clean Air Act, is also exempted.)

e. The addition or use of any system or device whose primary function is the reduction of air pollutants, except when an emission control system is removed or replaced by a system considered to be less efficient.

f. The relocation or change in ownership of an existing facility.

An increase in the production rate of an existing facility is designated as a modification only if there is an increase in the emission rate and the total cost necessary to accomplish the change constitutes a "capital expenditure." Capital expenditure is the product of the facility's original cost, as defined by Section 1012 of the Internal Revenue Code, and the appropriate "annual asset guideline repair allowance percentage" (AAGRAP). The 1978 edition of Internal Revenue Service Publication 534[3] sets the AAGRAP for the tire manufacturing industry at 5 percent. Therefore, if the total cost of increasing the production rate of an existing tire manufacturing facility exceeds 5 percent of the facility's original cost, and if this change causes increased emissions, the facility would be considered to have been modified.

Paragraph (b) clarifies what constitutes an increase in emissions in kilograms per hour and the procedures for determining the increase including the use of emission factors, material balances, continuous monitoring system and manual emission tests. Paragraph (c) affirms that the addition of a facility subject to performance standards to a stationary source does not make any other facility within that source subject to standards of performance. Paragraph (f) simply provides for superseding any conflicting provisions.

5.2.2 §60.15 Reconstruction

§60.15 states:

> "An existing facility, upon reconstruction, becomes an affected facility, irrespective of any change in emission rate. 'Reconstruction' means the replacement of components of an existing facility to such an extent that: (1) the fixed capital cost of the new components exceeds 50 percent of the fixed capital cost that would be required to construct a comparable entirely new facility, and (2) it is technologically and economically feasible to meet the applicable standards set forth in this part."[2]

The purpose of this provision is to ensure that an owner or operator does not perpetuate the lifetime of an existing facility by replacing all but vestigial components, support structures, frames, housing, etc., rather than totally replacing it in order to avoid subjugation to applicable standards of performance.

5.3 APPLICABILITY TO RUBBER TIRE MANUFACTURING PLANTS

5.3.1 General

Investigation of facilities for undertread cementing, sidewall cementing, tread end cementing, bead cementing, and green tire spraying shows that there are no specific practices by the industry which can readily be classified as modifications or reconstructions. The following sections are concerned with alteration and replacement practices common to these process facilities which limit the application of the modification and reconstruction provisions. In Section 5.3.2 other practices specific to each process facility are discussed.

5.3.1.1 Modifications. The emission of VOCs from the five VOC source process facilities is the result of application of solvent-based materials to tire components to improve adhesion during tire assembly or of application of solvent-based sprays to green tires to facilitate release from curing molds. Consequently, for rubber tire manufacturing any physical or operational change resulting in an increased emission rate to the atmosphere would be due to one or more of the following: (1) a production rate increase; (2) an increase in the VOC content of cement, solvent, or sprays; (3) an increase in the quantity of solvent applied per unit area of product.

5.3.1.1.1 Production rate increases. Any tire manufacturing plant is designed for a maximum production capacity, which is usually directly related to the maximum capacity of the tire building process facilities or the curing process facilities.[4] Facilities for other processes, such as those for undertread cementing, sidewall cementing, tread end cementing, bead cementing, and green tire spraying, may have capacities which exceed the total plant capacity for finished tires.[4] An increase in the production capacity of a plant is possible with a capital expenditure only for those facilities which limit finished tire production. For example, an increase in the plant production capacity could be met by the addition of a tire building machine or curing press. Any production rate increase which would exceed the capacity of existing process facilities would likely be met by the installation of new facilities to accommodate the production rate increase.[5,6] If the additional facility were one for which NSPS are established, it would be subject to NSPS if the addition caused an increase in VOC emissions and if the capital expenditure criteria were met.

5.3.1.1.2 Solvent-related VOC emission increases. Changes in solvent use practices may result in a rise of the VOC emission rate from tire manufacturing facilities. One possible change would be an increase in the VOC content of solvent, resulting in an increase in the quantity of VOCs emitted per unit of product. Such changes in solvent formulations are not common in the industry.[6,7]

Another possible change would be to increase the quantity of solvent or cement applied per unit of product. There is little incentive to do so since maximum bonding power is best effected by application of the thinnest complete layer of adhesive material. More solvent or cement applied per unit area of rubber would only reduce bonding power and increase costs.[7]

Either change would be classified as a modification if VOC emissions were to increase, causing the facility in question to become subject to standards of performance.

5.3.1.2 Reconstruction. Repair or rebuilding of an existing facility at a cost exceeding 50 percent of the cost of an entirely new facility is unusual. There are no general conditions which can be classified as a reconstruction. As stated in Section 5.3.1.1.1, production rate increases are usually met by adding to facilities rather than reconstructing existing facilities. Determination of whether any repair or rebuilding activities constitute reconstruction must be made on a case-by-case basis.

If a previously closed plant were to reopen, it would not be subject to NSPS unless one or more of the facilities for which standards had been promulgated were altered sufficiently to meet reconstruction criteria. Then, only those facilities which had been altered and for which standards exist would be subject to NSPS.

5.3.2 Applicability to Major Sources in Rubber Tire Manufacturing Plants

5.3.2.1 Undertread Cementing. The equipment used to cement undertread is simple, and little maintenance is required for most types of cement application systems. Cement applicator rolls, belts, or other conveyor system parts would only infrequently require replacement. Cement applicator brushes, where used, may require more frequent, though routine replacement. None of these cases should have an effect on VOC emissions, consequently, none is considered a modification.

Only a large-scale replacement of conveyor parts and cement applicator parts, either of which is considered an unusual circumstance, would approach 50 percent of the cost of replacing an entire undertread cementing facility. The determination of whether any rebuilding constitutes a reconstruction should be made on a case-by-case basis.

5.3.2.2 Sidewall Cementing. The equipment used to cement sidewalls is similar to that used to cement undertread. It is simple, and little maintenance is generally required. Parts would occasionally need routine replacement; but having no effect on VOC emissions, such replacement would not be considered a modification. Only in unusual circumstances would parts replacement approach 50 percent of the cost of replacing an entire sidewall cementing facility. The determination of whether any rebuilding constitutes a reconstruction should be made on a case-by-case basis.

5.3.2.3 Tread End Cementing. The equipment used to perform manual tread end cementing is very simple, including little specialized equipment other than a conveyor. Spray tread end cementing equipment is more complex, with sensors, spray arms, and nozzles requiring periodic adjustment or repair. For either cementing method, conveyor parts or cement application components would only rarely require replacement. Routine maintenance, repair, or replacement activities should not affect VOC emissions.

Replacement costs exceeding 50 percent of the cost of an entirely new facility would be incurred only in a very unusual situation, such as replacement of a major part of a spray cement application system and a large part of the conveyor system. Any determination of whether any rebuilding constitutes a reconstruction must be made on a case-by-case basis.

5.3.2.4 Bead Cementing. Bead cementing equipment, whether the cement is applied with a roller or swab, by dipping or by spraying, is very simple and requires little maintenance. The trough or dip tank containing cement must periodically be cleaned to remove rubber particles accumulated at the bottom or dried cement caked around the edges. Sponges, rollers, and nozzles must be periodically cleaned or replaced. These activities should not increase VOC emissions.

Repair or replacement costs exceeding 50 percent of the cost of an entirely new facility would be unusual. Any determination must be made on a case-by-case basis.

5.3.2.5 Green Tire Spraying. In a green tire spraying operation where solvent-based formulations are used, spray nozzles must be routinely cleaned or replaced due to abrasion; this should have no effect on VOC emissions. Other activities considered to be routine are clean-out of spray booths and mechanical maintenance of motorized rollers used in some operations to support green tires.

As with other processes, the primary determinants of VOC emissions from any green tire spraying facility are the VOC content of solvent-based sprays and quantity sprayed. Whether any changes in VOC content of sprays constitute a modification must be determined on a case-by-case basis.

Switching from solvent-based to water-based sprays requires several physical changes to a spraying unit. Piping, pumps, and nozzles used to convey solvent-based sprays must be replaced with corrosion-resistant material.[8,9] The booth itself may require replacement as the useful life of a carbon steel spray booth is lessened by the use of water-based sprays.[9] Additional conveyors may be necessary as use of water-based sprays requires longer drying time.[4] Whether the replacement of any of these components would constitute a reconstruction should be determined on a case-by-case basis. Replacement of an existing facility used for solvent-based sprays with a new facility used for water-based sprays would cause the new facility to be subject to standards of performance.

Switching from water-based to solvent-based sprays would be considered a modification since VOC emissions would increase. The change would be considered a reconstruction if appurtenant equipment alterations or replacements were to exceed 50 percent of the cost of an entirely new facility.

5.4 REFERENCES

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6.0 MODEL PLANTS AND REGULATORY ALTERNATIVES

The purpose of this chapter is to define model plants and to identify regulatory alternatives. Model plants are parametric descriptions of the types of plants and VOC-emitting facilities that are expected to be constructed by the tire manufacturing industry. They also represent the characteristics of existing plants where new, modified, or reconstructed VOC-emitting operations may be located. The regulatory alternatives are levels of emission reduction which EPA could use to limit the amount of VOCs released from tire plants. The model plant parameters are used as a basis for estimating the environmental, economic, emission reduction cost, and energy impacts associated with the application of the regulatory alternatives to the tire industry.

6.1 MODEL PLANTS

Parameters for undertread cementing, sidewall cementing, tread end cementing, bead cementing, and green tire spraying operations compose the model plants. Basic parameters for the model plants are shown in Tables 6-1, 6-2, and 6-3.

6.1.1 Model Plant Sizes

Analysis of the plant production rates that were presented in Table 3-1 indicates that no single model plant size based on production rate can adequately characterize existing plants and facilities or new ones likely to be built. Although manufacturing methods in small and large plants may be similar, VOC emission reduction cost factors may vary considerably. As a result, three model plant sizes are used for the environmental, energy, emission reduction cost, and economic impact analyses: model plants with production rates of 15,000 tires per day, 30,000 tires per day, and 50,000 tires per day. A distribution analysis of existing plant production rates indicates clustering around the production rates of 15,000 and 30,000 tires per day.

Table 6-1. OPERATING PARAMETERS FOR A 15,000 TIRES PER DAY
MODEL TIRE MANUFACTURING PLANT[1-26]
(Operating Time: 269 Days/Year)

Parameter	Emission Point					
	Undertread Cementing	Sidewall Cementing	Automatic Tread End Cementing	Manual Tread End Cementing	Bead Cementing	Green Tire Spraying
Number of Operations	3	3	3	3	2	4
Production Rate (Tire/Day/Unit)	5,000	5,000	5,000	5,000	7,500	3,750
VOC Emission Rate						
[kg (lb)/Day/Unit]	316 (697)	205 (453)	117 (258)	49 (107)	61 (134)	515 (1,134)
[kg (lb)/Day]	948 (2,090)	617 (1,359)	351 (774)	145 (321)	121 (268)	2,058 (4,537)
Exhaust Gas Flow Rate [m^3 (ft^3)/s/Unit]	1.73 (61.1)	1.46 (51.6)	2.67 (94.4)	2.83 (100.0)	3.30 (116.7)	1.65 (58.3)
VOC Concentration of Exhaust Gas [g/m^3 (lb/ft^3)]	2.11 (1.3×10^{-4})	1.63 (1.0×10^{-4})	0.51 (3.2×10^{-5})	0.20 (1.2×10^{-5})	0.21 (1.3×10^{-5})	3.61 (2.3×10^{-4})
Exhaust Gas Velocity [m (ft)/s]	10.2 (33.3)	10.2 (33.3)	10.2 (33.3)	10.2 (33.3)	10.2 (33.3)	10.2 (33.3)
Exhaust Gas Temperature [°C (°F)]	20 (68)	20 (68)	20 (68)	20 (68)	20 (68)	20 (68)
Control Technology*	CA,TI,CI	CA,TI,CI	CA,TI,CI	CA,TI,CI	CA,TI,CI	CA,TI,CI,WS

*CA = Carbon Adsorbers
TI = Thermal (Direct Flame) Afterburners
CI = Catalytic Afterburners
WS = Water-Based Sprays

Table 6-2. OPERATING PARAMETERS FOR A 30,000 TIRES PER DAY MODEL TIRE MANUFACTURING PLANT[1-26]
(Operating Time: 269 Days/Year)

	Emission Point					
Parameter	Undertread Cementing	Sidewall Cementing	Automatic Tread End Cementing	Manual Tread End Cementing	Bead Cementing	Green Tire Spraying
Number of Operations	4	5	4	4	3	5
Production Rate (Tire/Day/Unit)	7,500	6,000	7,500	7,500	10,000	6,000
VOC Emission Rate [kg (lb)/Day/Unit] [kg (lb)/Day]	474 (1,045) 1,896 (4,180)	247 (544) 1,233 (2,718)	175 (387) 702 (1,548)	73 (160) 291 (642)	81 (179) 243 (536)	823 (1,815) 4,116 (9,074)
Exhaust Gas Flow Rate [m^3 (ft^3)/s/Unit]	1.77 (62.5)	1.46 (51.7)	2.71 (95.8)	2.83 (100.0)	3.30 (116.7)	1.60 (56.7)
VOC Concentration of Exhaust Gas [g/m^3 (lb/ft^3)]	3.10 (1.9×10^{-4})	1.95 (1.2×10^{-4})	0.75 (4.7×10^{-5})	0.30 (1.9×10^{-5})	0.28 (1.8×10^{-5})	5.95 (3.7×10^{-4})
Exhaust Gas Velocity [m (ft)/s]	10.2 (33.3)	10.2 (33.3)	10.2 (33.3)	10.2 (33.3)	10.2 (33.3)	10.2 (33.3)
Exhaust Gas Temperature [°C (°F)]	20 (68)	20 (68)	20 (68)	20 (68)	20 (68)	20 (68)
Control Technology*	CA,TI,CI	CA,TI,CI	CA,TI,CI	CA,TI,CI	CA,TI,CI	CA,TI,CI,WS

*CA = Carbon Adsorbers
TI = Thermal (Direct Flame) Afterburners
CI = Catalytic Afterburners
WS = Water-Based Sprays

Table 6-3. OPERATING PARAMETERS FOR A 50,000 TIRES PER DAY MODEL TIRE MANUFACTURING PLANT[1-26]
(Operating Time: 269 Days/Year)

Parameter	Emission Point					
	Undertread Cementing	Sidewall Cementing	Automatic Tread End Cementing	Manual Tread End Cementing	Bead Cementing	Green Tire Spraying
Number of Operations	7	8	7	7	4	8
Production Rate (Tire/Day/Unit)	7,150	6,250	7,150	7,150	12,500	6,250
VOC Emission Rate [kg (lb)/Day/Unit] [kg (lb)/Day]	452 (996) 3,163 (6,974)	257 (566) 2,055 (4,530)	167 (368) 1,170 (2,579)	69 (153) 485 (1069)	101 (223) 405 (893)	857 (1,890) 6,860 (15,124)
Exhaust Gas Flow Rate [m^3 (ft^3)/s/Unit]	1.69 (59.5)	1.46 (51.7)	2.63 (92.9)	2.83 (100.0)	3.30 (116.7)1	1.59 (56.3)
VOC Concentration of Exhaust Gas [g/m^3 (lb/ft^3)]	3.09(1.9×10^{-4})	2.04(1.3×10^{-4})	0.74(4.6×10^{-5})	0.28(1.8×10^{-5})	0.35(2.2×10^{-5})	6.24(3.9×10^{-4})
Exhaust Gas Velocity [m (ft)/s]	10.2 (33.3)	10.2 (33.3)	10.2 (33.3)	10.2 (33.3)	10.2 (33.3)	10.2 (33.3)
Exhaust Gas Temperature [°C (°F)]	20 (68)	20 (68)	20 (68)	20 (68)	20 (68)	20 (68)
Control Technology*	CA,TI,CI	CA,TI,CI	CA,TI,CI	CA,TI,CI	CA,TI,CI	CA,TI,CI,WS

*CA = Carbon Adsorbers
TI = Thermal (Direct Flame) Afterburners
CI = Catalytic Afterburners
WS = Water-Based Sprays

Further, daily production rates for tire plants constructed since 1968 fall in a similar daily production distribution.[27,28] Two existing plants produce 48,000 or more tires per day.[29] In order to represent such large plants, a 50,000 tires per day model plant is included. Together, these three model plants should characterize the spectrum of tire manufacturing plant sizes likely to be constructed by the tire industry by 1985.

6.1.2 Operating Parameters

The average annual operating time for plants in the industry is about 269 days per year.[1-14] Assuming a 24-hour work day, plants operate approximately 6,456 hours per year.

The numbers of operations employed for solvent application activities, the unit production rates, the VOC emission rates, and the exhaust gas temperatures are based on industry-supplied information presented in Appendix C. Exhaust gas flow rates are based on maintenance of a 150 feet per minute face velocity in the capture system with all cement application equipment access doors open. A 100 feet-per-minute face velocity should be adequate; however, the 150 feet-per-minute face velocity assumes a 50 percent margin of safety.

Minimum capture system openings are based on industry-supplied information and observations at tire plants.[30-35] Allowances are given for air flow through permanent openings. For each operation, exhaust gas flow rates are sufficient to maintain VOC concentrations in the emission reduction system at 25 percent or less of the Lower Explosive Limit (LEL) of n-heptane, the compound with the lowest LEL of the major exhaust gas constituents. The need for unrestricted operator access requires a sizable opening in the capture system installed on certain operations. For example, tread end cementing and bead dipping operations may require larger openings in their capture systems than undertread or sidewall cementing. In the case of the model plant manual tread end cementing and bead dipping operations, large permanent openings in the capture system are included as the operator continually requires a comfortable and safe working area, while adequate face velocities are maintained. The capture system for the model plant automatic tread end cementing operation simply consists of an enclosure with two large detachable side panels for periodic operator access. Consequently, larger openings will increase the quantity of air which must be transported in order to capture and remove the pollutants.

The model plant flow rates reflect an approach to removal of VOCs which is a departure from current methods described in Chapters 3 and 4. Current methods rely on general or local ventilation for dilution and removal of VOCs. The capture systems used in the model plants are relied upon to contain VOC emissions at their source for transport to a control device. The lower model plant flow rates made possible by the capture systems may permit the use of fewer control devices in a plant since more operations could be connected to a single device.

Control technology useful for reduction of VOC emissions from solvent application operations in each model plant includes carbon adsorbers, thermal afterburners, and catalytic afterburners; of equal importance to the use of a control system is the use of an effective capture system. In many cases, tread end cementing and bead cementing are performed with techniques designed to minimize solvent use. VOC emission rates for such techniques are 10 grams or less per tire. Consequently, when used in conjunction with good work practices, these techniques could be used instead of emission reduction systems to minimize VOC releases to the ambient air. Material substitution of water-based sprays for organic solvent-based sprays can be used in place of VOC emission reduction systems for green tire spraying. The emission reduction systems, alternate methods of solvent application, and material substitution are described in Chapter 4.

6.2 BASIS FOR REGULATORY ALTERNATIVES

The purpose of this section is to identify regulatory alternatives for limiting VOC emissions from model plant undertread cementing, sidewall cementing, tread end cementing, bead cementing, and green tire spraying operations similar to the actual operations described in Chapter 3. Testing has been performed on one of the two undertread cementing VOC emission reduction systems currently employed within the tire manufacturing industry (Chapter 4). For tire manufacturing operations where no emission reduction systems are currently employed, the VOC emission capture components which meet the requirements of each regulatory alternative were based on designs transferred from applications in other industries; emission control components which are needed to meet the requirements of each regulatory alternative are substantiated by vendor quotations, literature references, and actual operating experiences where control components were used on exhaust streams having characteristics similar to those of the model plants. Testing has been performed on different methods of tread end cement and bead cement application in order to determine differences in VOC emissions and whether certain application methods may be used to meet the requirement of the regulatory alternatives. Vendor-supplied and tire industry-supplied information was used to compare VOC emissions due to water-based and organic solvent-based green tire spray technologies (Chapter 4.0).

VOCs from undertread cementing, sidewall cementing, tread end cementing, bead cementing, and green tire spraying can be reduced by the application of appropriate capture and control components. Due to the various machine configurations and the availability of different vapor capture methods, the design of the capture component must be adjusted to comply with physical limitations, such as cement/spray application apparatus dimensions, need for operator access, and available space in modified or reconstructed operations. Further, chemical characteristics of the solvent, such as evaporation rate and absorption by rubber materials, may affect capture component design. Consequently, physical limitations due to equipment or plant design and chemical characteristics of the solvents employed will affect capture efficiency. Hence, a single capture component design may not be adequate for all operations.[36]

Based on the review of control technology in Chapter 4, VOC emissions captured from tire manufacturing operations are most effectively reduced by adsorption or incineration. Adsorption of organic vapors contained in exhaust gases is achieved by the use of activated carbon. Incineration of exhaust streams containing VOCs can be accomplished by two methods: catalytic or direct-flame afterburners. It should be noted that the emission reduction systems presented in Chapter 4 are used to delineate environmental, economic, emission reduction cost, and energy impacts of the regulatory alternatives on model plants: it is not intended that any particular VOC emission reduction/control strategy be specified. Therefore, tire producers would not be constrained from selecting the most appropriate method of VOC emission reduction for their plants.

Substitution of water for organic solvents is an alternative method of reducing VOC emissions. The only current application of water-based technology is to green tire sprays, which are in wide use throughout the tire industry. There are no VOC emissions attributable to many water-based green tire sprays; water-based sprays which contain VOCs include them in such small amounts that very low quantities are emitted, and the use of emission reduction systems is not warranted.

Two regulatory alternatives have been identified:

1. Regulatory Alternative I - 70 percent average reduction for VOC emissions from undertread cementing, tread end cementing, bead cementing, and green tire spraying operations (sidewall cementing is not included);
2. Regulatory Alternative II - 75 percent reduction of VOC emissions from undertread cementing, sidewall cementing, tread end cementing, and bead cementing operations; 90 percent reduction of emissions from green tire spraying operations.

Regulatory Alternative I is equivalent to the emission reduction levels recommended in the EPA document, Control of Volatile Organic Emissions from Manufacture of Pneumatic Rubber Tires (CTG).[37] Again, it should be noted that the 70 percent value is the midpoint for the range of emission reductions available. Thus, actual emission reductions could deviate above or below this value. Regulatory Alternative II represents the level of emission reduction achieved with capture and control components which EPA believes to be adequately demonstrated while allowing for variations in equipment configuration, operator access, available space in modified or reconstructed operations, and chemical characteristics of the solvents employed. The emission reductions to be met under each regulatory alternative apply to the exhaust streams of the major VOC-emitting operations in tire manufacturing which can be treated effectively. Therefore, total emission reductions in each model plant would be less than the VOC emission reduction levels characterized by the regulatory alternatives. Regulatory Alternatives I and II are discussed in the following sections.

6.2.1 Regulatory Alternative I

Regulatory Alternative I represents the use of emission reduction systems to reduce VOC emissions from undertread cementing, tread end cementing, bead cementing, and green tire spraying operations. Application of these systems is detailed in the CTG.[37] Regulatory Alternative I represents the level of control that would be in effect in the absence of additional regulation. Since few existing SIPs include regulations which apply to rubber tire manufacturing, the regulatory baseline for 1985 is assumed to be equivalent to recommendations in the CTG.

Average capture efficiencies prescribed by the CTG for operations recommended for regulation range from approximately 65 to 85 percent: specific capture efficiencies are dependent on the type of solvent application activity on which the VOC emission reduction system capture component is installed.[37] It should be noted that sidewall cementing is not affected by Regulatory Alternative I. Expected capture efficiencies were reviewed in Table 3-8. VOCs in the exhaust stream of an operation's capture system component could be controlled by an afterburner or carbon adsorber achieving 90 to 95 percent efficiency.[37] Thus, general VOC emission reductions for affected facilities under Regulatory Alternative I range from 59 to 76 percent. Alternately, green tire spraying emissions can be reduced under Regulatory Alternative I (90 to 100 percent) by the substitution of water-based solvents for organic-based materials. VOC emission reductions recommended by Regulatory Alternative I are summarized in Table 6-4.

6.2.2 Regulatory Alternative II

Regulatory Alternative II recommends 75 percent reduction of VOC emissions from undertread cementing, sidewall cementing, tread end cementing, and bead cementing operations. VOC emissions from green tire spraying operations would be reduced by 90 percent. Reduction of VOC emissions from undertread cementing, sidewall cementing, tread end

Table 6-4. REGULATORY ALTERNATIVES FOR THE TIRE MANUFACTURING INDUSTRY[1-25,36,37]

Operation	Alternative I	Alternative II
Undertread Cementing	70%	75%
Sidewall Cementing	not applicable	75%
Tread End Cementing	70%	75%
Bead Cementing	70%	75%
Green Tire Spraying	70%	90%[a]

[a] Water-based sprays used.

cementing, and bead cementing operations is attainable by use of capture and control components similar to those discussed in Chapter 4. Water-based inside and outside green tire sprays have been demonstrated throughout the industry to be capable of reducing typical organic green tire spraying emissions by 90 percent or better. VOC emission reductions recommended for Regulatory Alternative II are summarized in Table 6-4.

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7.0 ENVIRONMENTAL IMPACT

This chapter presents an environmental impact assessment of the regulatory alternatives discussed in Chapter 6. The assessment includes primary, secondary, and incremental impacts associated with air quality, water quality, energy use, and solid waste disposal. Noise impacts, urban and community impacts, irreversible and irretrievable commitment of resources, and the impact of delaying implementation of the standard are also discussed.

Projected 1985 VOC emissions from operations to be included in standards of performance in tire manufacturing plants under Regulatory Alternative II are about 1,700 megagrams (1,880 tons), or about 50 percent less than projected new plant VOC emission levels in the absence of additional regulation (Regulatory Alternative I). Secondary pollutant emissions due to the use of afterburners or boilers for steam stripping carbon adsorber beds are anticipated to be minimal. Projected water pollution and solid waste disposal impacts are minimal in comparison to the large contribution of liquid and solid wastes from operations not related to VOC emission reduction in tire plants. The energy impact due to the use of VOC emission reduction systems is anticipated to be minor. Projected noise, urban, and community impacts due to implementation of any regulatory alternative are expected to be minimal. No irreversible or irretrievable commitments of resources are expected to be incurred under the regulatory alternatives. Detailed discussion of the environmental impacts is presented in the following sections.

7.1 AIR POLLUTION IMPACT

7.1.1 Primary Air Pollution Impact

The primary air pollution impact of each regulatory alternative is determined by comparison of projected VOC emissions from plants operating under Regulatory Alternative II in 1985 to projected VOC emissions from plants operating during 1985 with no additional regulations (Regulatory Alternative I). In order to analyze the incremental primary air quality impact of Regulatory Alternative II over Regulatory Alternative I, average annual model plant VOC emission rates under each regulatory alternative were determined and then used to project fifth-year (1985) impacts on national air quality.

7.1.1.1 Determination of Annual Uncontrolled Model Plant VOC Emission Rates. Annual uncontrolled VOC emission rates for each model plant size were determined using the following equation:

$$A_{iu} = (B_i \cdot C \cdot D_u) \frac{1 \text{ megagram}}{10^6 \text{ grams}} \qquad (1)$$

where A_{iu} is the annual uncontrolled VOC emission rate of model plant i in megagrams (i = 15,000, 30,000, or 50,000 tires per day);

B_i represents the daily tire production rate for model plant;

C is the number of days per year that the model plant is expected to operate (269 days per year);[1-14]

D_u represents the average total uncontrolled emission factor per completed tire (308.4 grams per tire).[1-25]

Therefore, the annual uncontrolled emission rates for a 15,000, 30,000 and a 50,000 tire per day model plant are 1,244 Mg (1,372 tons), 2,489 Mg (2,743 tons), and 4,148 Mg (4,572 tons), respectively. The daily model plant tire production rates and plant operating schedule in equation (1) were derived from industry-supplied information and are discussed in detail in Chapter 6. The average uncontrolled emission factor of 308.4 grams of VOC per tire represents the sum of the average emission factors for all VOC-emitting operations in a model tire manufacturing plant; this value does not include emission reduction contributions due to the use of water-based green tire sprays.

7.1.1.2 Determination of Annual Model Plant VOC Emission Rates Under Each Regulatory Alternative. Annual VOC emission rates for model plants designed to comply with Regulatory Alternatives I or II are calculated using the equation:

$$A_{ij} = \left(B_i \cdot C \cdot D_j\right) \frac{1 \text{ megagram}}{10^6 \text{ grams}} \qquad (2)$$

where A_{ij} is the annual VOC emission rate from model plant i in megagrams (i = 15,000, 30,000, or 50,000 tires per day), which uses an emission reduction system to meet the level of VOC emission reduction recommended under Regulatory Alternative j (j = I or II);

B_i represents the daily tire production rate for model plant i;

C is the number of days per year that the model plant is expected to operate (269 days per year);[1-14]

D_j represents total VOC emissions per completed tire under Regulatory Alternative j.

The total per-tire VOC emission factor for each regulatory alternative was derived from the relationship:

$$D_j = \Sigma[\text{grams of VOC per tire from each operation that is affected by Regulatory Alternative j}]\ (1-E_j) + \Sigma[\text{grams of VOC per tire from operations not controlled under Regulatory Alternative j}] \qquad (3)$$

E_j is the VOC emission reduction efficiency recommended for Regulatory Alternative j. E_I represents an average reduction of 70 percent for VOC emissions from undertread cementing, tread end cementing, bead cementing, and green tire spraying. Sidewall cementing is not included in E_I. E_{II} represents a 75 percent reduction in VOC emissions from undertread cementing, sidewall cementing, tread end cementing, and bead cementing; green tire spraying emissions are reduced by 90 percent. Therefore, 223.8 grams of VOC per tire are available from operations to be controlled under Regulatory Alternative I; 264.9 grams of VOC per tire (of which 137.2 grams are from green tire spraying) are available from operations controlled under Regulatory Alternative II.

The quantity of VOCs from operations that are not controlled change with each regulatory alternative. Operations not controlled under Regulatory Alternative I include sidewall cementing, tire building, finishing, curing, compounding, milling, extrusion, and calendering. Operations whose emissions are not controlled under Regulatory Alternative II include tire building, finishing, curing, compounding, milling, extrusion, and calendering. VOC emissions from operations that are not controlled under each regulatory alternative are 84.6 grams per tire (Regulatory Alternative I) and 43.5 grams per tire (Regulatory Alternative II). Therefore, the total per-tire VOC emission factor (including residual and uncontrolled emissions) for Regulatory Alternative I (D_I) is 151.7 grams and 89.1 grams for Regulatory Alternative II (D_{II}).[1-25]

Annual VOC emissions from 15,000, 30,000, and 50,000 tire per day model plants operating under Regulatory Alternative I are 612 Mg (675 tons), 1,224 Mg (1,349 tons), and 2,040 Mg (2,249 tons), respectively; annual VOC emissions from each size of model plant operating under Regulatory Alternative II are 360 Mg (349 tons), 719 Mg (793 tons), and 1,198 Mg (1,321 tons). The annual VOC emission rates for each model plant size are tabulated for each regulatory alternative and compared to the respective model plant's uncontrolled VOC emission rates in Table 7-1; VOC emission reductions beyond uncontrolled emissions are also presented. Overall emission reductions for model plants employing VOC emission reduction systems on the appropriate operations are approximately 50 percent under Regulatory Alternative I and 70 percent for Regulatory Alternative II. These values do not directly reflect the percent VOC emission reduction suggested for appropriate operations under each regulatory alternative, as uncontrolled VOC emissions from operations not affected by the regulatory alternatives are included.

7.1.1.3 Year 1985 Impact of Regulatory Alternatives on VOC Emissions. In order to project the future impact of the regulatory alternatives on air quality, two scenarios (Regulatory Alternatives I and II) were constructed. Year 1985 baseline emissions under Regulatory Alternative I were then compared to emissions projected for 1985 under Regulatory Alternative II. In order to estimate annual baseline VOC emissions from tire plants for 1985, the level of emission reduction for operations affected by Regulatory Alternative I in all plants was assumed to be equivalent to the average level of emission reduction recommended in the EPA document, Control of Volatile Organic Emissions from Manufacture of Pneumatic Rubber Tires (CTG).[26] Under Regulatory Alternative II, all plants which have new, modified, or reconstructed operations in place between 1980 and 1985 would reduce VOC emissions to the extent recommended by Regulatory Alternative II; the extent of emission reduction in

Table 7-1. IMPACT SUMMARY OF VOC EMISSIONS FROM MODEL TIRE MANUFACTURING PLANTS[1-25]

Model Plant Size (tires per day)	VOC EMISSION RATE[a]			REDUCTION IN UNCONTROLLED VOC EMISSIONS[a]	
	Uncontrolled	Regulatory Alternative I	Regulatory Alternative II	Regulatory Alternative I	Regulatory Alternative II
15,000	1,244 (1,372)	612 (675)	360 (396)	632 (697)	884 (974)
30,000	2,489 (2,743)	1,224 (1,349)	719 (793)	1,265 (1,394)	1,770 (1,951)
50,000	4,148 (4,572)	2,040 (2,249)	1,198 (1,321)	2,108 (2,324)	2,950 (3,252)

[a] All values are expressed in Megagrams (tons) per year.

all plants with no new, modified, or reconstructed operations would be to the level described for Regulatory Alternative I. For the purposes of this primary air pollutant impact assessment, plants were assumed to have either all new, modified, or reconstructed operations, or existing operations only. Further, plants having new, modified, or reconstructed affected operations will be referred to as "new" plants and all others as "existing plants."

VOC emissions for year 1985 were projected through the equation:

$$A_j = {}_x (B_x \cdot C \cdot D_{xj}) \frac{1 \text{ megagram}}{10^6 \text{ grams}} \qquad (4)$$

where: A_j is the total amount of VOC emitted under Regulatory Alternative j (j = I or II)

B_x is the daily quantity of tires manufactured during 1985 in plant type x (x = existing or new);

C is the annual average number of plant operating days (269 days/year);[1-25]

D_{xj} is the total per tire VOC emission factor for plant type x under Regulatory Alternative j (j = I or II; x = existing or new).

The overall growth rate of tire production for the 5-year period, 1980 to 1985, was determined in order to calculate the 1985 daily production rates of new and existing plants. The overall annual growth rate for tire production was extrapolated from the annual growth rates for original equipment and replacement market tire production in conjunction with the proportion of total production devoted to each market. The annual growth rates of the original equipment and replacement markets are 2 percent and 1 percent, respectively; the average original equipment share is 30 percent of the total market.[27] Thus, an average annual growth rate of 1.3 percent is projected for the domestic tire industry. The average annual growth rate is then multiplied by the January 1, 1980, daily tire production value (984,100) to produce the total 1985 daily tire production rate.[28] The apportioning of production for existing plants and new plants was determined by assuming that 3.78×10^7 radial tires per year (140,520 tires per day) will be produced by new plants, while older bias plants are closed (refer to Chapter 9.0 for further discussion of the radial tire value). Thus, daily tire production rates for existing plants and all new plants are projected to be 909,230 and 140,520 tires per day, respectively.

Each total per-tire VOC emission factor (D_{xj}) calculated using equation (3) represents per-tire emissions from existing and new plants. All undertread cementing, tread end cementing, and bead cementing operations of existing plants would have 70 percent efficient VOC emission reduction systems installed; green tire spraying operations not using water-based sprays would also use 70 percent efficient VOC emission reduction systems. For the purposes of projecting primary air pollution impacts, the proportion of existing plants using water-based green tire sprays in 1985 is assumed to be the same as year 1979 non-attainment area water-based green tire spray consumption. Under this assumption, 82 percent of all existing tire production would use inside water-based green tire sprays; 54 percent of all existing tire production would use outside water-based sprays.[15-25] Therefore, the total per-tire VOC emission factor for existing plants is 134.2 grams (0.296 lb) per tire. Under Regulatory Alternative I, all new plants would reduce VOC emissions to the extent recommended in the CTG.[26] Further, the proportion of new production that uses water-based green tire sprays in 1985 is assumed to be equivalent to the nationwide proportion of tire production that used water-based sprays in year 1979 (82 percent of all inside sprays, 54 percent of all outside sprays used). Therefore, the total per-tire VOC emission factor for new plants under Regulatory Alternative I is 134.2 grams (0.296 lb) per tire. Year 1985 annual VOC emissions from new plants under Regulatory Alternative I are projected to be 5,073 megagrams (5,592 tons); total annual emissions for year 1985 are estimated to be 37,896 Mg (41,773 tons).

The total per-tire VOC emission rates for all existing plants remain constant under Regulatory Alternative II; the levels of VOC emission reduction recommended under Regulatory Alternative II yield a new plant total per-tire emission factor of 89.1 grams (0.196 lb) per tire. Therefore, year 1985 annual VOC emissions from new plants operating under Regulatory Alternative II are projected to be 3,368 megagrams (3,713 tons) per year; total annual emissions for year 1985 are estimated to be 39,191 megagrams (39,899 tons).

An inventory of estimated 1985 VOC emissions from existing plants and new plants under Regulatory Alternatives I and II is presented in Table 7-2. Average VOC emission reductions attributable to Regulatory Alternative II are 1,705 megagrams (1,879 tons): this represents a 50 percent decrease in emissions from all new plants and a 5 percent reduction from nationwide baseline emissions. The small difference in percent VOC reduction between the nationwide baseline (Regulatory Alternative I) and Regulatory Alternative II emissions is due to the large proportion of VOC emissions contributed by existing plants and the wide, voluntary use of water-based green tire sprays.

7.1.2 Secondary Air Pollution Impact

Secondary air pollutants are those emissions which are not usually associated with an uncontrolled facility, but which result from the use of pollution control equipment. VOC emission control equipment which may be incorporated into model plant VOC emission reduction systems include carbon adsorbers or afterburners.

Secondary air pollution problems due to the use of carbon adsorption by the manufacturers are expected to be minimal. Odorous and irritating gases may be emitted if the VOC stream contacts the carbon bed before it is adequately cooled following desorption.[29] Following proper procedures while regenerating the carbon beds should eliminate thermal decomposition of VOCs. Secondary air pollutants generated by the boiler used in producing steam for carbon bed desorption include particulates, sulfur oxides (SO_x), carbon monoxide, incomplete combustion products, and nitrogen oxides (NO_x). Particulate and sulfur oxide emissions from fuel combustion are regulated by State Implementation Plans (SIPs) which follow the guidelines set forth in EPA regulations on the Preparation of Implementation Plans [40 CFR 51].[30] These guidelines provide for particulate and SO_x emission reduction through exhaust gas treatment. An alternative method for SO_2 emission control is the combustion of low sulfur fuels.[30] Provided exhaust gas treatment, low sulfur fuels oil, or natural gas is used, the amount of particulate and SO_x emissions generated during steam stripping of the carbon beds should be minimal in relation to the magnitude of VOC emission reductions. Depending on the model plant size and regulatory alternative involved, annual NO_x emissions due to steam stripping of carbon beds are estimated to range from

Table 7-2. 1985 VOC EMISSIONS INVENTORY FOR U.S. TIRE MANUFACTURING PLANTS[1-25]

Plant Designation	Daily Tire Production Rate	VOC Emission Factor- Grams (pounds) Per Tire		Annual VOC Emission Rate- Megagrams (Tons) Per Year[a]	
		Regulatory Alternative I	Regulatory Alternative II	Regulatory Alternative I	Regulatory Alternative II
Existing plants	909,230	134.2 (0.296)	134.2 (0.296)	32,823 (36,181)	32,823 (36,181)
New plants	140,520	134.2 (0.296)	89.1 (0.196)	5,073 (5,592)	3,368 (3,713)
Total	1,049,750	-	-	37,896 (41,773)	36,191 (39,894)

[a] Based on a 269-day per year operating schedule.

approximately 0.3 megagrams (0.3 tons) to 1.9 megagrams (2.1 tons). NO_x emissions are calculated by multiplying the annual fuel requirements of the boiler under each regulatory alternative (Sections 7.4 and 8.1) by the NO_x emission factor of 2.8 kilograms per 1,000 liters of distillate oil (22 pounds per 1,000 gallons).[31] Annual NO_x emissions from boilers used for steam stripping carbon adsorber beds in model plants are presented as Table 7-3.

Afterburner exhaust may contain some secondary pollutants. Excessive NO_x emissions in the afterburner exhaust may be due to several factors, but the problem can be mitigated. A discussion of NO_x emissions associated with afterburner use is presented in Chapter 4. Annual NO_x emissions from afterburner exhaust of model plant VOC emission reduction systems are estimated to range from 12.9 megagrams (14.2 tons) to 44.0 megagrams (48.5 tons); the amount depending on the model plant size, afterburner type, and regulatory alternative involved.[31] Annual NO_x emissions from model plant afterburner control components are presented as Table 7-4. Incomplete combustion of VOCs passing through the afterburner may create a larger nuisance than the original substance: incompletely combusted hydrocarbons may be more potent smog precursors than the VOCs used at the tire plant. If the afterburner is designed to achieve 95 percent removal efficiencies and is maintained properly, partially combusted VOCs should not be emitted. Sulfur and halogens in the exhaust stream can produce SO_x and noxious gases when burned.[32] Existing SIPs should require the use of low sulfur fuels or treatment of afterburner exhaust streams that are contaiminated with sulfur or halogen compounds, thereby negating SO_x pollution problems.

Secondary air pollutants from VOC emission reduction systems are not expected to be significant, especially when compared to the contribution of pollutants from other operations in the plant. Fuel combustion for VOC emission reduction systems represents less than 1 percent of a model plant's total fuel demand (Section 7.4). If all combustion facilities in a plant were to use similar fuels, secondary pollutant emissions from VOC emissions reduction systems would be expected to increase total plant emissions by less than 1 percent. Secondary air pollutant impacts are also not expected to be significant when considering

Table 7-3. ANNUAL NITROGEN OXIDES (NO_x) EMISSIONS FOR BOILERS USED ON CARBON ADSORBERS IN MODEL PLANTS[31]

Model Plant Size Tires/Day	Regulatory Alternative	Annual Fuel Requirement liters	(gallons)	Annual NO_x Emissions[b] megagrams	(tons)
15,000	I	217,000	(57,300)	0.6	(0.7)
	II	132,000	(34,900)	0.4	(0.4)
30,000	I	433,000	(115,000)	1.2	(1.3)
	II	264,000	(63,900)	0.7	(0.8)
50,000	I	721,000	(191,000)	2.0	(2.2)
	II	439,000	(116,000)	1.2	(1.4)

[a] No. 2 oil heating value: 3.95×10^{-2} gigajoules/liter (141,850 Btu/gallon).

[b] NO_x emission factor: 2.8 kilograms NO_x/1000 liters (22 pounds NO_x/ 1000 gallons)

Table 7-4. ANNUAL NITROGEN OXIDE (NO_x) EMISSIONS DUE TO THE USE OF AFTERBURNERS[31]

Model Plant Size (tires per day)	Regulatory Alternative	VOC Control Component	Annual Fuel Requirement[a] liters	Annual Fuel Requirement[a] (gallons)	VOCs Combusted Annually[b] liters	VOCs Combusted Annually[b] (gallons)	Annual NO_x Emissions[c] megagrams	Annual NO_x Emissions[c] (tons)
15,000	I	Thermal afterburner	5.52×10^6	(1.46×10^6)	9.43×10^5	(2.49×10^5)	18.1	(19.9)
		Catalytic afterburner	3.67×10^6	(9.69×10^5)	9.43×10^5	(2.49×10^5)	12.9	(14.2)
	II	Thermal afterburner	6.22×10^6	(1.64×10^6)	5.74×10^5	(1.52×10^5)	19.0	(21.0)
		Catalytic afterburner	4.23×10^6	(1.12×10^6)	5.74×10^5	(1.52×10^5)	13.4	(14.8)
30,000	I	Thermal afterburner	7.13×10^6	(1.88×10^6)	1.89×10^6	(4.99×10^5)	25.2	(27.9)
		Catalytic afterburner	4.68×10^6	(1.24×10^6)	1.89×10^6	(4.99×10^5)	18.4	(20.3)
	II	Thermal afterburner	8.91×10^6	(2.35×10^6)	1.15×10^6	(3.04×10^5)	28.2	(31.0)
		Catalytic afterburner	6.05×10^6	(1.60×10^6)	1.15×10^6	(3.04×10^5)	20.2	(22.2)

Table 7-4. ANNUAL NITROGEN OXIDE (NO_x) EMISSIONS DUE TO THE USE OF AFTERBURNERS[32] (Concluded)

Model Plant Size (tires per day)	Regulatory Alternative	VOC Control Component	Annual Fuel Requirement[a] liters	Annual Fuel Requirement[a] (gallons)	VOCs Combusted Annually[b] liters	VOCs Combusted Annually[b] (gallons)	Annual NO_x Emissions[c] megagrams	Annual NO_x Emissions[c] (tons)
50,000	I	Thermal afterburner	1.12×10^7	(2.95×10^6)	3.14×10^6	(8.30×10^5)	40.0	(44.1)
		Catalytic afterburner	7.56×10^6	(2.00×10^6)	3.14×10^6	(8.30×10^5)	30.0	(33.0)
	II	Thermal afterburner	1.39×10^7	(3.68×10^6)	1.91×10^6	(5.05×10^5)	44.4	(48.9)
		Catalytic afterburner	9.51×10^6	(2.51×10^6)	1.91×10^6	(5.05×10^5)	32.0	(35.3)

[a] Average heating value of No. 2 oil: 3.95×10^{-2} gigajoules/liter (141,850 Btu/gallon).

[b] (5.49 pound/gallon VOC).

[c] NO_x emissions: (Fuel requirement + VOCs combusted) NO_x emission factor[d] $\frac{\text{1 megagram}}{\text{1000 kilograms}}$.

[d] NO_x emission factor for distillate oil: 2.8 kilograms NO_x/1000 liters oil (22 pounds NO_x/1000 gallons oil).

the extent of VOC emission reduction achieved by the carbon adsorbers or afterburners; on a mass basis, secondary air pollutant emissions are estimated to be 1 percent or less than emissions from uncontrolled operations.

7.2 WATER POLLUTION IMPACT

The impact of the VOC emission reduction systems on water quality is presented in this section. Afterburner components used in the VOC emission reduction systems are not expected to use or discharge water. Therefore, the water impact of afterburners is negligible. The water impacts of emission reduction systems useing carbon adsorbers are determined by quantifying the effluents and constituent pollutants that are discharged from the VOC reduction systems employed in the model plants under each regulatory alternative. The effluent values determined for each alternative are then compared to the total process and nonprocess wastewater characteristics in order to determine the significance of the additional wastewater streams. Applicable water pollution regulations are reviewed to determine if pollutants discharged in the adsorber effluent will adversely affect plant compliance with existing discharge limits. Where applicable, control techniques which would mitigate water pollution impacts are discussed. No unavoidable impacts due to discharge of carbon adsorber effluent could be characterized; consequently, unavoidable water impacts are not discussed. Finally, pollutant discharges associated with each regulatory alternative are extrapolated to estimate their contribution to the tire industry's fifth-year water pollution impact.

7.2.1 Characterization of Model Plant Wastewater Discharges

In order to assess the water pollution impact associated with Regulatory Alternatives I and II, data pertaining to the quantity and quality of wastewater streams generated by an uncontrolled entire plant were collected. Table 7-5 characterizes the baseline wastewater discharges for plants in operation since 1959.[33-35] Values presented in Table 7-6 were converted from reported values by assuming:

- 1,055 kilograms of raw materials are used to manufacture 1,000 kilograms of finished product;[34]

Table 7-5. WASTEWATER CHARACTERISTICS FOR A TIRE MANUFACTURING PLANT NOT EMPLOYING VOC CONTROLS[33,a]

Wastewater Flow	126.3 liters (33.4 gallons) per tire
Pollutant Load:	
Chemical Oxygen Demand (COD)	7.0 grams (0.015 pounds) per tire
Suspended Solids (SS)	3.7 grams (0.008 pounds) per tire
Total Dissolved Solids (TDS)	66.6 grams (0.147 pounds) per tire
Oil and grease	0.5 grams (0.001 pounds) per tire

[a] Includes utility wastewaters.

Table 7-6. FIFTH-YEAR MODEL PLANT WASTEWATER DISCHARGES DUE TO CARBON ADSORPTION CONTROL COMPONENTS[33,35]

[liters/year (gallons/year)]

Model Plant Size (tires per day)	Wastewater Flow for Tire Manufacturing and Non-process Operations[a]	Wastewater Flow Associated With VOC Emission Reduction System Employing Carbon Adsorption Control Components	
		Regulatory Alternative I	Regulatory Alternative II
15,000	5.10×10^8 (1.35×10^8)	2.52×10^6 (6.68×10^5)	2.06×10^6 (5.44×10^5)
30,000	1.02×10^9 (2.09×10^8)	5.06×10^6 (1.34×10^6)	4.12×10^6 (1.09×10^6)
50,000	1.70×10^9 (4.48×10^8)	8.43×10^6 (2.23×10^6)	6.87×10^6 (1.81×10^6)

- the representative tire mass is 11.5 kg.[1-14]

A typical tire plant generates 126.3 liters (33 gallons) of wastewater for each tire produced.[33] Noncontact heating and cooling represent the majority of the water requirement.[33] Discharges from service utilities and other nonprocess facilities substantially contribute to pollutant loading.[33] Intermittent process wastewater discharges include production equipment effluent, washdown of processing areas, runoff from raw material storage, and spills or leakage of organic solvents, lubricating oils, and miscellaneous solutions used in tire manufacturing.

7.2.2 Water Pollution Impact of the Regulatory Alternatives

Increased wastewater flows and pollutant loadings due to the use of carbon adsorbers and water-based solvent green tire sprays for VOC emission reduction are discussed below.

Total VOC emissions that are available from operations under each of the regulatory alternatives were previously estimated to be 223.8 grams per tire for Regulatory Alternative I and 127.7 grams per tire for Regulatory Alternative II.[1-25] The VOC emission reduction system efficiencies are expected to be 70 percent for Regulatory Alternative I and 75 percent for Regulatory Alternative II; green tire spraying is not included in this section of the Regulatory Alternative II impacts as the operation does not employ an emission reduction system. Solvent recovery from the carbon adsorber control component was assumed to be approximately 99 percent efficient. Therefore, overall solvent recovery efficiencies from the VOC emission point to decanting of recovered solvent are approximately 70 percent for Regulatory Alternative I and 75 percent for Regulatory Alternative II. Multiplying a steam requirement of 4.0 kilograms of steam per kilogram desorbed VOCs (4 pounds of steam per pound of desorbed VOCs)[35] by the affected facilities' available VOC emission factor and the average VOC emission reduction efficiency for each regulatory alternative yields the average per-tire wastewater discharges associated with each level of VOC emission reduction. The wastewater discharges due to air pollution control are converted from mass values to volume using the density of water (1.0 gram per cubic centimeter) and are presented in Table 7-6. Fifth-year water pollution impacts of Regulatory Alternative I appear to be greater than the impacts of Regulatory Alternative II: emission reduction systems are employed for organic solvent-based green tire spray operations under Regulatory Alternative I; no emission reduction systems are needed for the water-based sprays. The additional wastewater generated by the carbon adsorber component under each regulatory alternative represents less than 1.0 percent of the total wastewater discharge attributable to tire production and nonprocess operations.

Pollutants contained in the carbon adsorber effluent following solvent decanting are expected to be minimal as approximately 98 percent by volume of the solvents used by the tire manufacturers are virtually insoluble in water.[1-25,36] The vapor pressures of the specific solvents used in tire production indicate that most of the solvent that escapes decanting will volatilize after discharge from the adsorber. Therefore, the wastewater impact due to employment of a carbon adsorber as the VOC emission reduction system control component is minimal. The water solubilities and vapor pressures of solvents used for the facilities recommended for regulation are summarized in Table 7-7.

Water pollution impacts due to the use of water-based green tire sprays are expected to be minimal: all water applied to the tires during spraying evaporates.[36] Most wastewater from green tire overspray is expected to evaporate since small quantities of green tire spray (less than 50 grams per tire) are applied.[37-41]

7.2.3 Applicable Water Pollution Regulations

The EPA Effluent Guidelines for Water Quality Standards [40 CFR 428] apply limitations to total suspended solids, oil/grease, and pH discharge in effluents from rubber tire manufacturing plants.[42] The effluent limitations are presented as Table 7-8. Since the use of proposed VOC emission reduction systems is anticipated to have only a minimal impact on the total plant process and nonprocess wastewater burden, the regulatory alternatives probably will not be affected to a great extent by 40 CFR 428. In the event that toxic or nonconventional (nondegradable) substances are discharged in the carbon adsorber effluent, the Pretreatment Standards for New Sources [40 CFR 128 and 403] will apply.[43,44] It is not expected that carbon adsorber wastewater will contain toxic or nonconventional substances; therefore, the pretreatment standards will not be further discussed.[1-25]

Table 7-7. SOLVENT VAPOR PRESSURES AND SOLUBILITY IN WATER[1-14,36]

Solvent	Proportion of Solvent Used by the Tire Industry (Percent by Volume)	Vapor Pressure (mm Hg)	Solubility In 100 Parts Water[a]
Naphtha	90	40-100 @ 20°C (68°F)	i
n-Heptane	6	40 @ 22°C (72°F)	0.005 @ 15°C (60°F)
n-Hexane		100 @ 16°C (60°F)	0.014 @ 15°C (60°F)
Toluene	2	20 @ 18°C (65°F)	0.05 @ 15°C (60°F)
Isopropanol	1	40 @ 24°C (75°F)	S
Others[b]	1	----	---

[a] i = insoluble

S = totally soluble

[b] Other solvents used by the tire industry include:

- Trichloroethene
- Tetrachloroethane
- Pentachloroethane
- Carbon tetrachloride
- Xylene
- Kerosene
- Diethyl Ether
- Gasoline

Table 7-8. U.S. ENVIRONMENTAL PROTECTION AGENCY EFFLUENT LIMITATIONS FOR RUBBER PROCESSING[42]

EFFLUENT CHARACTERISTICS	EFFLUENT LIMITATIONS	
	One-day maximum	Daily average[a]
Total Suspended Solids Kilograms per megagram (pounds per 1000 pounds of raw material	0.096	0.064
Oil/grease Kilograms per megagram (pounds per 1000 pounds) of raw material	0.024	0.016
pH	6.0-9.0	6.0-9.0

a. For 30 consecutive days.

The use of carbon adsorbers as the control component of the VOC emission reduction system is not anticipated to significantly increase the discharge of waterborne pollutants into the environment. The major constituents of the model plant wastewater stream are contributed by operations other than air pollution control. Therefore, if a new plant is constructed with the Best Available Technology Economically Achievable (BATEA) to treat process and nonprocess wastewater streams, the plant should continue to meet water quality standards when wastewater increments from the carbon adsorber control component of the VOC emission reduction system are included.

7.2.4 Pollutant Discharge Treatment Techniques

Pollutants recovered from the carbon adsorber can be removed from the condensed steam by using an aspirator or a mechanical decanter. Once the solvents are recovered to the fullest extent practical, the water may be discharged into an oil-water wastewater separator with effluent from other portions of the plant.[33] Engineering judgment indicates that the few VOCs remaining in the decanting water will volatilize or be removed by the wastewater separator.

7.2.5 Projected Fifth-Year Water Quality Impact

The small quantities of water from carbon adsorbers and low solubility of the recovered compounds in the wastewater from the carbon adsorber control component is anticipated to have only a minimal effect when it is combined with the large volume of wastewater and mass of pollutants generated by process and nonprocess operations in the tire plant. VOC emission reduction systems that employ afterburner control components are not expected to use or discharge water. Therefore, the fifth-year water pollution impact of the proposed regulatory alternatives is expected to be minimal.

7.3 SOLID WASTE DISPOSAL IMPACT

The quantity of solid wastes generated by existing tire manufacturing practice amounts to approximately 5.5 percent of the total weight of product or 167.4 megagrams (184.5 tons) per year for the tire industry.[1-14,34] The components of these wastes include rubber, metal, textile material, and nonprocess rubbish.[34] The sources and relative magnitudes of each solid waste component are listed in Table 7-9.

Table 7-9. SOLID WASTES DUE TO TIRE MANUFACTURING[34]

Material	Weight Percent of Total	Source(s)
Rubber	20	Tires rejected during quality control, experimental and test products, in-process trimmings, curing bladders, and molding waste
Metal	20	Defective material and trimming from wire bead preparation and steel cord and belt processing
Textiles	10	Fabric cord and belt in reject tires
Rubbish	50	Contaminated raw material containers

Rubber wastes from tire manufacturing are currently disposed of in sanitary landfill, by shipment to reclaiming operations, or recycled for use as raw material in low-quality goods; the latter technique is limited by product mix.[34,45,46] Scrap metal is handled by general collection measures and hauled to available dumping locations, as is the case for paper and wood waste and textile material in reject tires.[34] Defective textile fabric, trimmings, and uncured tire carcasses are often sold to scrap dealers for distribution to the mechanical rubber goods industry.[34]

A potential adverse impact on solid waste disposal associated with the proposed regulatory alternatives is the handling of spent carbon from adsorption systems. Typically, the weight of the carbon bed can be determined by the equation:

$$M_{ij} = (K_{ij} \cdot T) \qquad (5)$$

where M_{ij} is the carbon weight per bed (in megagrams) for model plant i and Regulatory Alternative j
(i = 15,000, 30,000, or 50,000 tires per day)
(j = I or II);
K_{ij} is the exhaust gas flow rate (in cubic feet per minute for model plant i and Regulatory Alternative j;
T is the ratio of carbon to flow rate, equal to 0.5 pounds carbon per cubic feet per minute of airflow.

Three carbon beds are considered necessary to handle the model plant's facilities exhaust flow while adequately treating VOC emissions throughout the plants' operating hours.[35] Thus M_{ij}, the weight of the carbon bed, is tripled in order to arrive at the total amount of carbon required for the VOC emission reduction system used in the model plants under each regulatory alternative. Activated carbon has an average useful life of five years,[35] thus M_{ij} is divided by five to obtain annual carbon disposal requirements for each model plant. The activated carbon disposal requirements for the model plants under each regulatory alternative are presented in Table 7-10.

Fifth-year impacts on solid waste disposal are expected to be minimal. The increase in model plant solid waste due to employment of carbon adsorption is expected to be insignificant (less than 0.003 percent). Table 7-11 summarizes the waste disposal impacts of the proposed regulatory alternatives.

Table 7-10. FIFTH-YEAR ACTIVATED CARBON REQUIREMENTS FOR MODEL PLANTS UNDER REGULATORY ALTERNATIVES I AND II[35]

Model Plant Size (tires Per day)	Total Emission Reduction System Exhaust Gas Flow Rate[a] [m^3/sec (ft^3/min)]		Activated Carbon Requirement[b] [megagrams (tons) per year]	
	Regulatory Alternative I	Regulatory Alternative II	Regulatory Alternative I	Regulatory Alternative II
15,000	22.4 (47,500)	24.5 (51,800)	6.5 (7.1)	7.0 (7.8)
30,000	29.9 (63,500)	35.6 (75,500)	8.6 (9.5)	10.3 (11.3)
50,000	47.3 (100,500)	55.9 (118,500)	13.7 (15.1)	16.1 (17.8)

[a] For all activities to be affected by the regulatory alternatives.

[b] Three carbon beds for each activity affected.

Table 7-11. FIFTH-YEAR SOLID WASTE IMPACTS ON MODEL TIRE MANUFACTURING PLANTS DUE TO THE USE OF CARBON ADSORPTION CONTROL COMPONENTS[1-14,27,34,35]

Model Plant Size (tires per day)	Projected Fifth-Year Solid Waste Generation [megagrams (tons)]	Projected Fifth-Year Solid Waste Generated By VOC Emission Reduction Systems Employing Carbon Adsorber Control Components [megagrams (tons)]	
		Regulatory Alternative I	Regulatory Alternative II
15,000	2,552 (2,707)	6.5 (7.1)	7.0 (7.8)
30,000	5,104 (5,415)	8.6 (9.5)	10.3 (11.3)
50,000	8,507 (9,025)	13.7 (15.1)	16.1 (17.8)

[a] Average tire weight: 11.5 kilograms (24.4 pounds); 5.5 percent of the finished tire weight represents solid waste generated during tire manufacture. Solid waste due to activated carbon is not included.

Spent activated carbon can be disposed of in at least two ways: incineration and sanitary landfill.[47] Incineration has the ability to significantly reduce the volume of solid waste generated, but may create potential air pollution problems through release of incomplete combustion products. Liquid waste due to exhaust gas scrubbers employed on the solid waste incinerators may also pose problems.[47] Sanitary landfill probably represents the most desirable method for spent carbon disposal. Proper solid waste disposal procedures will restrict water movement through the adsorbant and migration of adsorbed materials into the groundwater, thereby mitigating potential groundwater pollution due to solid waste disposal.

7.4 ENERGY IMPACT

7.4.1 Total Process and Nonprocess Energy Consumption

Tire manufacturing plants consume energy for tire production and nonprocess applications in the form of electricity, fuel oil, natural gas, and occasionally, coal. Mechanical energy is required for processing equipment such as the compounders, mills, calenders, and extruders. Thermal energy is employed for drying dipped fabric, as well as molding and curing tires. Plant lighting and ventilation represent nonprocess energy consumption.

Industry-supplied information was used to estimate total 1977 energy consumption by tire manufacturing plants.[1-14] The total annual energy consumption is presented as Table 7-12. Average heating values used to convert the various energy sources to a standard unit include:

natural gas - 3.14×10^{-5} gigajoules/meter^3 (1,050 Btu/ft^3);
coal (national average) - 3.15×10^{-2} gigajoules/kilogram
(13,530 Btu/lb);
No. 2 fuel oil - 3.95×10^{-2} gigajoules/liter (141,850 Btu/gal);
No. 5 fuel oil - 4.13×10^{-2} gigajoules/liter (148,100 Btu/gal);
No. 6 fuel oil - 4.22×10^{-2} gigajoules/liter (151,350 Btu/gal);
propane - 2.55×10^{-2} gigajoules/liter (91,500 Btu/gal).[34]

Total 1977 energy consumption for reporting tire plants was 1.34×10^9 gigajoules per year. 2.1×10^8 tires were produced by these plants in 1977;[48] thus, the average amount of energy consumed to produce a tire is

Table 7-12. 1977 TIRE INDUSTRY ENERGY CONSUMPTION[1-14,48]

Plant Code	1977 Energy Consumption (gigajoules per year)	Plant Code	1977 Energy Consumption (gigajoules per year)
A	2.52×10^6	X	1.10×10^6
B	2.04×10^6	Y	1.09×10^6
C	1.17×10^6	Z	1.43×10^6
D	1.51×10^6	AA	1.38×10^6
E	2.40×10^6	BB	7.01×10^5
F	5.55×10^5	CC	8.77×10^5
G	7.26×10^5	DD	1.03×10^6
H	1.65×10^6	EE	1.33×10^6
I	1.66×10^6	FF	4.06×10^5
J	1.55×10^6	GG	1.51×10^6
K	6.22×10^8	HH	1.75×10^8
L	9.92×10^5	II	1.91×10^6
M	2.56×10^5	JJ	2.73×10^6
N	5.16×10^5	KK	1.46×10^6
O	5.67×10^5	LL	2.09×10^5
P	2.35×10^5	MM	1.47×10^5
Q	5.86×10^5	1977 Total[a]	1.38×10^9
R	5.33×10^5		
S	1.57×10^5		
T	7.51×10^4		
U	1.63×10^6		
V	1.06×10^9		
W	6.01×10^5		

[a] represents reporting tire plants only.

6.7 gigajoules. This value represents an average value and does not reflect the actual amount of energy consumed to produce any specific type or size of tire. The energy required to produce a tire in 1980 is not expected to change as most plants included in the 1977 energy use survey are still in operation. Thus, if 2.7×10^8 tires are produced in 1980,[15] the total annual tire industry demand without air pollution controls installed is estimated to be 1.78×10^9 gigajoules.

7.4.2 Energy Requirements for VOC Emission Reduction Systems

The energy requirements for the VOC emission reduction systems can be divided into electrical and fuel demands. Electricity demands for the emission reduction systems are due to the energy required to run fans, pumps, and the control panel. Fuel is required to produce steam to regenerate carbon beds in the adsorber control component and to incinerate VOCs in the afterburner control component.

Electrical requirements of the VOC emission reduction systems were calculated from system design parameters and vendor quotations.[34,49-51] In-depth discussion of the methods used to determine electrical requirements of the emission reduction system is presented in Section 8.1 and in Capital and Operating Costs of Selected Air Pollution Control Systems.[35]

The fuel required to produce steam to regenerate carbon adsorber beds can be expressed as:

$$R_{ij} = Q_{ij} \cdot S \cdot [H/E_B] \cdot C \qquad (6)$$

where R_{ij} is the annual fuel requirement (in Btus) for model plant i under Regulatory Alternative j (i = 15,000, 30,000, or 50,000 tires per day) (j = I or II);

Q_{ij} represents the quantity of VOCs adsorbed daily (in pounds) for model plant i under Regulatory Alternative j;

S is the steam requirement of 4.0 pounds per pound of VOCs desorbed;[35]

H is the Btu requirement to produce superheated steam (40 pounds per square inch at 300°F) from 68°F water (1186.6 Btu per pound of steam);[36,52]

E_B represents an average steam boiler efficiency (80 percent);[52]

C is the average number of days per year that a model plant is expected to operate (269 days per year).[1-14]

The fuel requirements for the afterburner control components are determined by the equation:

$$F_{ij} = [(T_1-T_o)(V_{ij})1.08] - U_{ij}W \quad - \quad T_1 -[(T_1-T_o)(1-X) + T_o]1.08\ V_{ij} \quad (7)$$

where:

F_{ij} is the hourly fuel requirement (in Btus) for the afterburner control component in model plant i under Regulatory Alternative j (i = 15,000, 30,000, or 50,000 tires per day) (j = I or II);

T_1 is the afterburner temperature in °F;

T_o is the temperature at zero enthalpy (60°F);

V_{ij} represents the flow rate through the control component in model plant i under Regulatory Alternative j (i = 15,000, 30,000, or 50,000 tires per day) (j = I or II);

U_{ij} is the VOC emission rate (pounds per hour) from the capture component in model plant i under Regulatory Alternative j;

W represents the average heating value of the VOCs in the exhaust stream (10,700 Btu per pound of VOC);[36]

X is the heat recovery efficiency of the control component (40 percent for thermal and catalytic afterburners).[49,51]

The value of 1.08 represents a conversion factor for changing the units of temperature and flow into units of Btus per hour. The emission reduction system's operating assumptions used in calculating afterburner fuel requirements are further discussed in Section 8.1.

VOC emission reduction system annual energy requirements are presented for each model plant and regulatory alternative and compared to total plant energy requirements in Table 7-13. The percentage of energy required to operate the VOC emission reduction system is small when compared to the overall energy demands of the model plant. Energy requirements for systems using carbon adsorber control components are estimated to be less than 0.03 percent of the total plant energy demand. Afterburners may require up to 1.0 percent of the plant's total energy demand.

Energy consumption may be affected by the capture components used to meet the recommended regulatory alternatives: general ventilation

Table 7-13. PROJECTED ANNUAL ENERGY REQUIREMENTS FOR MODEL PLANT VOC EMISSION REDUCTION SYSTEMS[1-25,35,36,51,52]

Model Plant Size (tires per day)[a]	Model Plant Energy Requirement (gigajoules per year)[b]	Regulatory Alternative	VOC Emission Reduction System Energy Requirement (gigajoules per year)		
			Carbon Adsorber Employed	Thermal After-burner Employed	Catalytic After-burner Employed
15,000	2.71×10^{7}	I	8.56×10^{3}	2.18×10^{5}	1.45×10^{5}
		II	5.21×10^{3}	2.46×10^{5}	1.67×10^{5}
30,000	5.42×10^{7}	I	1.71×10^{4}	2.82×10^{5}	1.85×10^{5}
		II	1.04×10^{4}	3.52×10^{5}	2.39×10^{5}
50,000	9.03×10^{7}	I	2.85×10^{4}	4.41×10^{5}	2.99×10^{5}
		II	1.74×10^{4}	5.51×10^{5}	3.76×10^{5}

[a] Plants operate 269 days per year.

[b] VOC emission reduction system energy requirements are not included. Average energy requirement: 6.71 gigajoules per tire.

requirements may be reduced in some areas of a plant as the capture component may keep workplace concentrations of VOCs within OSHA employee exposure limits. However, the tremendous amounts of heat generated by tire production equipment may require that present general ventilation practices be maintained in order to control the temperature of the working environment.[45]

7.5 OTHER IMPACTS

7.5.1 Noise Impacts

The proposed regulatory alternatives are not anticipated to have significant noise impacts on the plant environment. The emission reduction systems should not produce excessive noise if they are operating properly. If noise problems persist following repair of the emission reduction system, acoustical damping may be necessary.[53] Earplugs should be worn by employees only in areas where acoustical damping is not feasible.[53]

7.5.2 Urban and Community Impacts

The fifth-year annualized cost analysis described in Section 9.3 indicates that the projected costs are well below the 100 million dollar level, which according to Executive Order 12291,[54] signifies a major regulation. It is also anticipated in Section 9.3 that the cost of implementing the regulatory alternatives would have minimal impacts upon new plant profitability. Under these conditions, the decision to construct new tire plants should be unaffected by the proposed regulatory alternatives. Consequently, none of the regulatory alternatives are expected to have an adverse impact on tire industry employment trends, thereby reducing the probability that adverse urban and community impacts will be experienced.

7.5.3 Irreversible and Irretrievable Commitment of Resources

The VOC emission reduction systems proposed for installation in new tire plants represent technology transfer from other industries. Therefore, it is possible that the emission reduction systems presented in this document are not the most effective that can be installed. The VOC emission reduction system designs presented in previous chapters are not intended to be strictly adhered to; rather they represent basic emission reduction technology that can be applied to VOC-emitting facilities in tire plants in order to meet the proposed regulatory alternatives. New technology that is demonstrated to reduce VOC emissions to levels comparable to the model VOC reduction systems can be used, thereby allowing each company to develop the optimal system for each plant. Therefore, the regulatory alternatives are not expected to adversely affect future VOC control options.

7.5.4 Impact of a Delayed Standard

Assuming that emission factors for VOC-emitting facilities and activities do not increase, the fifth-year impact of delaying implementation of the standard for VOC emissions from tire manufacturing plants is an increase in VOC emissions from new plants by about 1,693 megagrams (1,866 tons) per year. Consequently, a delay in implementation of the standard would effectively increase national VOC emissions from tire manufacturing operations by about 5 percent.

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8.0 COSTS

8.1 COST ANALYSIS OF VOC EMISSION REDUCTION SYSTEMS

8.1.1 Introduction

This section presents an analysis of the costs to design, purchase, install, and operate VOC emission reduction systems which may be used by the rubber tire industry to meet the emission reduction levels recommended for the regulatory alternatives. Twenty-seven combinations of control devices and capture components servicing applicable VOC-emitting operations are sized and the costs analyzed for each regulatory alternative, model plant, and one-line retrofit situation. The general design of these systems is discussed in Chapter 4. The cost combinations are summarized in Table 8-1. Analysis performed on these VOC emission reduction systems includes capital costs, annualized costs, and cost effectiveness. The results of the analysis are used in Section 9.2 to determine the economic impacts on the tire industry. A cost analysis was performed for additional emission reduction systems where various combinations of operations were manifolded into the same control component. The cost analysis for these additional systems is not included in this section but is included in the docket. The most likely combinations of solvent application operations to be controlled under the regulatory alternatives will be discussed.

The emission reduction systems are designed to remove VOCs from the exhaust gas streams, as described by the model plant parameters in Chapter 6, to the extent suggested by Regulatory Alternatives I and II. Table 8-2 summarizes the uncontrolled exhaust gas parameters for those tire manufacturing operations to which VOC emission reduction systems may be applied.

Table 8-1. COST COMBINATIONS USED FOR THE COST ANALYSIS
OF MODEL PLANT VOC EMISSION REDUCTION SYSTEMS[a]

Undertread cementing[a]
Sidewall cementing[b]
Manual tread end cementing[a]
Automatic tread end cementing[a]
Bead dipping[a]
Organic green tire spraying[c]
Water-based green tire spraying[a]
Undertread cementing/manual tread end cementing[d]
Undertread cementing/automatic tread end cementing[d]

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[a] Included in Regulatory Alternatives I and II for one-line retrofits and all model plant sizes.

[b] Not included in Regulatory Alternative I.

[c] Not included in Regulatory Alternative II.

[d] Not included in one-line retrofit cost analysis.

Table 8-2. UNCONTROLLED EXHAUST GAS PARAMETERS FOR MODEL RUBBER TIRE MANUFACTURING PLANTS[1-25]

Model Plant Size Tires/day	Operation	Exhaust Gas Velocity m/sec (ft/min)	Exhaust Gas Flow Rate[a] m^3/sec (ft^3/min)	VOC Concentration in Exhaust Gas g/m^3 (lb/ft^3)[b]	Organic Solvent Consumption Rate kg/day (lb/day)
15,000	Undertread cementing	10.2 (33.3)	5.19 (11,000)	2.11 (1.3×10^{-4})	948 (2,090)
	Sidewall cementing	10.2 (33.3)	4.40 (9,300)	1.63 (1.0×10^{-4})	617 (1,359)
	Manual tread end cementing	10.2 (33.3)	8.50 (18,000)	0.2 (1.2×10^{-5})	145 (321)
	Automatic tread end cementing	10.2 (33.3)	8.02 (17,000)	0.5 (3.2×10^{-5})	351 (774)
	Bead cementing	10.2 (33.3)	6.61 (14,000)	0.2 (1.3×10^{-5})	121 (268)
	Green tire spraying[c]	10.2 (33.3)	6.61 (14,000)	3.6 (2.3×10^{-4})	2,058 (4,537)
30,000	Undertread cementing	10.2 (33.3)	7.08 (15,000)	3.1 (1.9×10^{-4})	1,896 (4,180)
	Sidewall cementing	10.2 (33.3)	7.33 (16,000)	1.9 (1.2×10^{-4})	1,233 (2,718)
	Manual tread end cementing	10.2 (33.3)	11.33 (24,000)	0.3 (1.9×10^{-5})	291 (642)
	Automatic tread end cementing	10.2 (33.3)	10.86 (23,000)	0.7 (4.7×10^{-5})	702 (1,548)
	Bead cementing	10.2 (33.3)	9.91 (21,000)	0.3 (1.8×10^{-5})	243 (536)
	Green tire spraying[c]	10.2 (33.3)	8.02 (17,000)	5.9 (3.7×10^{-4})	4,116 (9,074)
50,000	Undertread cementing	10.2 (33.3)	11.8 (25,000)	3.1 (1.9×10^{-4})	3,163 (6,974)
	Sidewall cementing	10.2 (33.3)	11.7 (25,000)	2.0 (1.3×10^{-4})	2,055 (4,530)
	Manual tread end cementing	10.2 (33.3)	19.8 (42,000)	0.3 (1.8×10^{-5})	485 (1,069)
	Automatic tread end cementing	10.2 (33.3)	18.4 (39,000)	0.7 (4.6×10^{-5})	1,170 (2,579)
	Bead cementing	10.2 (33.3)	13.2 (28,000)	0.3 (2.2×10^{-5})	405 (893)
	Green tire spraying[c]	10.2 (33.3)	12.7 (27,000)	6.2 (3.9×10^{-4})	6,860 (15,124)

[a] Temperature of exhaust gases from applicable operations is 20°C (68°F).

[b] Assuming 100 percent of VOC consumed is emitted.

[c] Organic solvent only.

Regulatory Alternatives I and II are analyzed for their cost impacts. Both regulatory alternatives would affect VOC emissions from undertread cementing, tread end cementing, bead cementing, and green tire spraying operations. Regulatory Alternative II would additionally affect VOC emissions from sidewall cementing. An in-depth discussion of the regulatory alternatives is presented in Chapter 6. The regulatory alternatives and VOC emission reduction systems for applicable rubber tire manufacturing operations are summarized in Table 8-3.

A number of operating assumptions are made in order to estimate capital expenditures, annualized costs, and cost effectiveness of model plant emission reduction systems. The noncorrosive character of the VOC exhaust stream allows for the control components to be package units. The entire emission reduction system is assumed to operate 24 hours per day for 269 days per year: the average number of days that a model plant would be expected to operate.[1-14] For the purpose of sizing afterburners, exhausted gases are assumed to contain a maximum VOC concentration that is less than 25 percent of the lower explosive limit. Intermittent use of solvents in some activities may occasionally result in exhaust gas VOC concentrations approaching 0 percent of the LEL.[1-14] Capture component design and dimensions for model plant solvent application areas are derived from measurements of existing capture components, capture components planned for new plants, dimensions of solvent application areas having no exhaust gas capture apparatus, and technology transfer from other industries. Model VOC emission rates, solvent evaporation (flashoff rates, and attendant conveyor speeds) were established in order to determine the additional conveyor enclosure required to capture VOCs under each regulatory alternative. The cost of the additional conveyor needed to extend beneath the capture hoods is not included as the incremental costs incurred by installation of additional conveyor in the model plants would not significantly affect the results of the cost analysis.[48-50] Other assumptions applicable to the cost analysis are discussed in the following sections and are summarized in Tables 8-4 through 8-6.

8.1.2 New Operations

All costs are based on the parameters of the three sizes of model plants presented in Tables 6-1 through 6-3. These model plants are

Table 8-3. REGULATORY ALTERNATIVES AND VOC EMISSION REDUCTION SYSTEMS FOR APPLICABLE RUBBER TIRE MANUFACTURING FACILITIES

Regulatory Alternative	Facilities	VOC Emission Capture Component Efficiency (percent)	VOC Emission Control Component Efficiency (percent)[32-47]
I[a]	Undertread cementing	75	carbon adsorber: 90-95 direct flame afterburner: 90-95[d] catalytic afterburner: 90-95[d]
	Tread end cementing[b]	75	
	Bead cementing	75	
	Green tire sprayingc	75	
II	Undertread cementing	80	carbon adsorber: 95 direct flame afterburner: 95[d] catalytic afterburner: 95[d]
	Sidewall cementing	80	
	Tread end cementing[b]	80	
	Bead cementing	80	
	Green tire spraying[c]	N/A	

[a] Based on values from Control of Volatile Organic Emissions from Manufacture of Pneumatic Rubber Tires.[26]

[b] Manual and automatic cement application.

[c] 95 to 100 percent reduction in emissions via material substitution.[26-31]

[d] 45 percent efficient primary heat recovery installed.[40-44]

Table 8-4. ASSUMPTIONS USED IN DEVELOPING COST ESTIMATES FOR CARBON ADSORBERS

Packaged unit designated for new source installation.

Fixed, regenerative bed design.

Automatic and continuous operation.

Operating hours: 6456 hr/yr.[1-14]

Operating temperature: 38°C (100°F).[26]

Gas stream constituents: 90% naphtha, 6% n-hexane or n-heptane, 2% toluene, 1% isopropyl alcohol, 1% other VOCs.[1-14]

Maximum VOC concentration in exhaust stream: 9.1 g/m^3 (5.7×10^{-4} lb/ft^3).[1-14]

Life of activated carbon: 5 years.[44,45,51]

Electricity cost (10/79): $0.055/kWh.[51]

Activated carbon cost (12/79): $4.40/kg ($2.00/lb).[46]

Steam cost (12/79): $11.10/Mg ($5.04/10^3 lb).[51]

Cooling water cost: $0.03/$10^3$ liters ($0.116/$10^3$ gallons)[51]

Waste disposal cost (12/79): $11/Mg ($10/ton).[51]

Direct operating labor cost (12/79): $7.82/hr x 0.5 hr/shift x 807 shifts/yr = $3155/yr.[51,52]

Supervisory operating labor cost (12/79): 15% of direct operating labor cost = $475/yr.[51,52]

Maintenance labor costs: $8.60/hr x 0.5 hr/shift x 807 shifts/yer = $3470[51]

Maintenance material costs: 100% of maintenance labor costs[51]

Operating supply costs: 15% of annual maintenance costs.[53]

Plant overhead: 8% of operating labor and maintenance labor.[51]

Discount interest rate: 10%.[51]

Capital recovery period: 15 years.[51]

Capital recovery factor: 13.15% of fixed capital costs.

Taxes: 1% of fixed capital costs.[51]

Insurance: 1% of fixed capital costs.[51]

Administration and permits: 2% of fixed capital costs.[51]

Market value of naphtha (1/80): $1.21/gal.[54]

Market value of hexane (1/80): $0.60/gal.[54]

Market value of heptane (1/80): $0.59/gal.[54]

Market value of toluene (1/80): $1.36/gal.[54]

Market value of isopropyl alcohol (1/80): $1.33/gal.[54]

Table 8-5. ASSUMPTIONS USED IN DEVELOPING COST ESTIMATES FOR DIRECT FLAME AFTERBURNERS

Packaged unit designated for new source installation.

Multi-jet nozzle burner arrangements with 45% efficient primary heat recovery.[42-44]

Afterburner temperature: 760°C (1400°F).[42-44]

Vapor residence time: 0.5 seconds[51]

Fuel used: #2 oil.

Operating hours: 6456 hr/yr.[1-14]

Exhaust stream constituents: 90% naphtha, 6% n-hexane or n-heptane, 2% toluene, 1% isopropyl alcohol, 1% other VOCs.[1-14]

Concentration of VOCs in exhaust stream: 1% to 25% of the LEL.

Refractory life: 5 years[51]

Electricity cost (10/79): $0.055/kWh.[51]

Cost of #2 fuel oil (1/80): $4.77/GJ ($5.03/10^6 Btu).[55]

Direct operating labor cost (12/79):
$7.82/hr x 0.5 hr/shift x 807 shifts/yr = $3155/yr.[51,52]

Supervisory operating labor cost (12/79):
15% of direct operating labor costs = $475/yr.[51,52]

Maintenance labor costs:
$8.60/hr x 0.5 hr/shift x 807 shift/hr = $3470.[51]

Maintenance material costs: 100% of maintenance labor costs[51]

Operating supply costs: 15% of annual maintenance costs.[53]

Plant overhead: 80% of operating labor and maintenance labor costs.[51]

Discount interest rate: 10%.[51]

Capital recovery period: 10 years.[51]

Capital recovery factor: 16.27% of fixed capital costs.

Taxes: 1% of fixed capital costs.[51]

Insurance: 1% of fixed capital costs.[51]

Administration and permits: 2% of fixed capital costs.[51]

Table 8-6. ASSUMPTIONS USED IN DEVELOPING COST ESTIMATES FOR CATALYTIC AFTERBURNERS

Packaged unit designated for new source installation.

Multifire or vortimetric burner arrangement.

Precious metal catalyst in honeycomb configuration; mounted on carbon or ceramic supports.

Heat recovery efficiency: 45%.[40,41]

Afterburner temperature: 480°C (900°F).[40,41]

Space velocity: 60,000 hr^{-1}.[40,41]

Fuel used: #2 oil.

Operating hours: 24 hr/day x 269 days/yr = 6456 hr/yr.[1-14]

Exhaust stream constituents: 90% naphtha, 6% n-hexane or n-heptane, 2% toluene, 1% isopropyl alcohol, 1% other VOCs.[1-14]

Concentration of VOCs in exhaust stream: 1% to 25% of the LEL.

Refractory life: 5 years[51]

Catalyst life: 5 years.[51]

Electricity cost (10/79): $0.055/kWh.[51]

Cost of #2 fuel oil (1/80): $4.77/GJ ($5.03/10^6 Btu).[55]

Direct operating labor cost (12/79):
$7.82/hr x 0.5 hr/shift x 807 shifts/yr = $3155/yr.[51,52]

Supervisory operating labor cost (12/79):
15% of direct operating labor cost = $475/yr.[51,52]

Maintenance labor costs: $8.60/hr x 0.5 hr/shift x 807 shift/hr = 3470[51]

Maintenance material costs: 100% of maintenance labor costs[51]

Operating supply costs: 15% of annual maintenance costs.[53]

Plant overhead: 80% of operating labor and maintenance labor costs.[51]

Discount interest rate: 10%.[51]

capital recovery period: 10 years.[51]

Capital recovery factor: 16.27%

Taxes: 1% of fixed capital costs.[51]

Insurance: 1% of fixed capital costs.[51]

Administration and permits: 2% of fixed capital costs.[51]

used in order to obtain complete and consistent cost information. Three model plant sizes were used since no single model plant size can adequately describe existing plants or plants likely to be built. In order to generate cost information for additions in existing plants, model plant parameters of retrofit single units were chosen for each facility: the parameters for each one-line retrofit were based on the parameters of single model plant units having the highest production rates.

These costs do not represent the actual amounts of money spent for any particular plant. Rather, the costs relate to models which represent estimates of additional lines and plants likely to be built. The costs of VOC emission reduction systems will vary according to production rate, production equipment used, plant layout, and geographic location.[45,56] For example, installation costs in different geographic regions have been reported to vary from 15 percent to 400 percent of the freight-on-board (f.o.b.) cost of a carbon adsorber.[45]

Two categories of costs are derived using the model plant parameters: capital and annualized costs. The annualized costs, in conjunction with the model plant parameters, are used to generate information on the cost effectiveness of the VOC emission reduction systems.

8.1.2.1 Capital Costs. Capital costs represent the financial resources required to plan, fabricate, install, and test run (shakedown) the VOC emission reduction system. These costs can be divided into direct and indirect capital costs. Direct capital costs represent the investment needed to purchase and install a VOC emission reduction system. Indirect capital costs cover engineering, contractors' fees, field overhead, shipping, shakedown, spares, performance testing, and taxes. In addition to direct and indirect capital costs, a contingency factor is included to account for any unforeseen costs encountered during planning, fabrication, and installation of the equipment.[47] Table 8-7 presents the magnitudes of the component capital cost factors described above.

8.1.2.1.1 Determination of capital costs. In order to be able to arrive at the total installed capital cost of any emission reduction system using the capital cost component factors, the cost to purchase

Table 8-7. COMPONENT CAPITAL COST FACTORS FOR A MODEL TIRE PLANT AS A FUNCTION OF PURCHASED EQUIPMENT COST, Q[51]

Component	Cost Factor
Direct Costs	
Purchased equipment costs	
control device[a]	
auxilliary equipment[b]	1.00 C_{PE}
instruments and controls	0.30 C_{PE}
taxes	0.05 C_{PE}
freight	0.05 C_{PE}
Total purchased equipment costs	1.00 Q
Installation Costs	
foundations and supports	0.08 Q
erection and handling	0.21 Q (0.29 Q)[c]
electrical	0.04 Q
piping	0.02 Q
insulation	0.01 Q
painting	0.01 Q
site preparation	0.00 Q
facilities and buildings	--
Total installation costs	0.37 Q (0.45 Q)[c]
Total Direct costs	1.37 Q (1.45 Q)[c]
Indirect Costs	
engineering and supervision	0.20 Q
construction and field expenses	0.05 Q
construction fee	0.10 Q
start up	0.01 Q
performance test	0.01 Q
model study	none
contingencies	0.30 Q
Total Indirect costs	0.67 Q
Total Capital Costs	2.04 Q (2.12 Q)[c]

[a] includes control equipment, instrumentation, fan, electrical equipment, and steam regenerator.

[b] includes hooding, ductwork, fans, motors, belts, stack, and fabrication labor.

[c] retrofit situation.

the system (Q) must be determined. The component cost factor Q does not include installation costs, but does include instrumentation, taxes, and freight. VOC emission reduction systems are divided into two parts:

1. the exhaust gas containment and transport system (capture system),
2. the VOC emission control device.

For solvent application activities, the capture system should be designed to remove VOC emissions from cement, solvent, or spray application equipment and VOCs from evaporation of solvent that is applied to the cemented or sprayed material. A detailed discussion of these principles is presented in Chapter 4. The dimensions of model plant application area exhaust stream capture components are derived from dimensions of existing and planned VOC emission capture components; dimensions of the solvent application apparatus or stations not having exhaust stream capture components; and transfer of capture component designs from other industries. Enclosures used on conveyors following cement application areas are designed to compliment the application area component: the enclosure is extended to allow 75 percent (Regulatory Alternative I) or 80 percent (Regulatory Alternative II) of the total emissions available from solvent application to be captured. The length of conveyor enclosure employed in the capture system is determined by the solvent flashoff rate and conveyor speed (nominally 0.46 meters per second [90 ft/min]).[57-59] Conveyor enclosures are not included for organic green tire spraying operations as the coated tires would reside in the spray booths to facilitate the recommended level of VOC capture. Water-based green tire spray booths would not require conveyors and conveyor enclosures, but would require the installation of a particulate control component with appurtenant ducting. Since both green tire spraying technologies would be expected to require the use of a particulate control device in the absense of VOC controls, the costs of particulate control equipment for green tire spraying operations are not included in the cost analysis.[57-59] The capital costs of exhaust stream pretreatment for operations other than green tire spraying are not considered since industry-supplied information and plant visits indicate the use of such VOC emission reduction system components is not usually necessary.[1-14,57-59,60] Once the capture components are sized, material costs are determined by translating the dimensions (plate area) into the weight of carbon steel required. Fabrication labor costs are based on capture component plate area, the weight of material required, and complexity of construction. The procedure used to develop material and fabrication labor costs is outlined in Capital and Operating Costs of Selected Air Pollution Control Systems (GARD Manual).[51]

The dimensions of the capture component, along with the assumption that the capture component is designed to operate with all application area access panels open in order to maintain effective capture during line changes and machinery adjustment, are used to establish the captured exhaust flow rates. The flow rates for the capture components servicing the different solvent application activities are presented in Table 8-8. The duct diameters then are determined as a function of the flow rate and the duct velocity to be maintained. For volatile organic gases, a duct velocity of about 10 m/sec (2,000 ft/min) should be maintained.[51,61,62] The purchase cost per linear foot of duct is determined as a function of the duct diameter and the thickness of carbon steel used, which is 12.7 mm (0.5 in) for VOC capture systems. The costs of duct elbows, transitions, and "tees" are also determined as a function of the duct diameters and material thickness used (12.7 mm). Calculations of duct costs are presented in the GARD Manual.[51] Model plant duct lengths are determined using nominal distances between solvent application operations and the location of the VOC emission control component.[57-59,60]

Capital costs of fans and motors used to transport exhausted gases for the VOC emission capture system depend on the control system to be used and the length of ducting involved. Pressure drops due to ducting are approximately 1/10" W.G. per 100 ft. of duct.[61,62] Carbon adsorbers experience pressure drops of 15" to 20" Water Gauge (W.G.),[45,51] while afterburner pressure drops are approximately 6" (direct flame) to 10" W.G. (catalytic) when heat recovery is used.[51] Therefore, fan sizes and motor horsepower requirements for a carbon adsorber would,

Table 8-8. CAPTURED EXHAUST GAS PARAMETERS
15,000 Tire Per Day Model Plant

Operation (Regulatory Alternative)		Flow Rate		Temperature		Captured Exhaust Gas VOC Emission Rate	
		m^3/sec	(scfm)	°C	(°F)	kg/day	(lb/day)
Undertread cementing	(I)	3.78	(8,000)	20	(68)	710	(1565)
	(II)	5.19	(11,000)	20	(68)	760	(1670)
Sidewall cementing	(I)	N/A		20	(68)	N/A	N/A
	(II)	4.40	(9,000)	20	(68)	495	(1090)
Manual tread end cementing	(I)	7.55	(16,000)	20	(68)	110	(240)
	(II)	8.50	(18,000)	20	(68)	115	(255)
Automatic tread end cementing	(I)	6.14	(13,000)	20	(68)	265	(580)
	(II)	8.02	(17,000)	20	(68)	280	(620)
Bead dipping	(I)	5.19	(11,000)	20	(68)	90	(200)
	(II)	6.61	(14,000)	20	(68)	95	(215)
Organic solvent-based green tire spraying	(I)	6.61	(14,000)	20	(68)	1545	(3405)
	(II)[a]	6.61	(14,000)	20	(68)	1645	(3630)

Table 8-8. CAPTURED EXHAUST GAS PARAMETERS (Continued
15,000 Tire Per Day Model Plant

Operation (Regulatory Alternative)		Flow Rate		Temperature		Captured Exhaust Gas VOC Emission Rate	
		m^3/sec	(scfm)	°C	(°F)	kg/day	(lb/day)
Water-based green tire spraying	(I)	N/A		20	(68)	N/A	
	(II)	N/A		20	(68)	N/A	
Undertread and manual tread end cementing[b]	(I)	11.33	(24,000)	20	(68)	820	(1810)
	(II)	13.69	(29,000)	20	(68)	875	(1930)
Undertread and automatic tread end cementing[b]	(I)	9.91	(21,000)	20	(68)	975	(2150)
	(II)	13.22	(28,000)	20	(68)	1040	(2290)

Table 8-8. CAPTURED EXHAUST GAS PARAMETERS (Continued)
30,000 Tire Per Day Model Plant

Operation (Regulatory Alternative)		Flow Rate m^3/sec	Flow Rate (scfm)	Temperature °C	Temperature (°F)	Captured Exhaust Gas VOC Emission Rate kg/day	Captured Exhaust Gas VOC Emission Rate (lb/day)
Undertread cementing	(I)	5.19	(11,000)	20	(68)	1420	(3135)
	(II)	7.08	(15,000)	20	(68)	1515	(3345)
Sidewall cementing	(I)	N/A		20	(68)	N/A	N/A
	(II)	7.33	(16,000)	20	(68)	985	(2175)
Manual tread end cementing	(I)	9.91	(21,000)	20	(68)	220	(480)
	(II)	11.33	(24,000)	20	(68)	235	(515)
Automatic tread end cementing	(I)	8.50	(18,000)	20	(68)	525	(1160)
	(II)	10.86	(23,000)	20	(68)	560	(1240)
Bead dipping	(I)	7.55	(16,000)	20	(68)	180	(400)
	(II)	9.91	(21,000)	20	(68)	195	(430)
Organic solvent-based green tire spraying	(I)	8.02	(17,000)	20	(68)	3090	(6805)
	(II)[a]	8.02	(17,000)	20	(68)	3295	(7260)

Table 8-8. CAPTURED EXHAUST GAS PARAMETERS (Continued)
30,000 Tire Per Day Model Plant

Operation (Regulatory Alternative)		Flow Rate m^3/sec	(scfm)	Temperature °C	(°F)	Captured Exhaust Gas VOC Emission Rate kg/day	(lb/day)
Water-based green tire spraying	(I)	N/A		20	(68)	N/A	
	(II)	N/A		20	(68)	N/A	
Undertread and manual tread end cementing[b]	(I)	15.10	(32,000)	20	(68)	1640	(3615)
	(II)	18.41	(39,000)	20	(68)	1750	(3855)
Undertread and automatic tread end cementing[b]	(I)	13.69	(29,000)	20	(68)	1950	(4295)
	(II)	17.94	(38,000)	20	(68)	2080	(4580)

Table 8-8. CAPTURED EXHAUST GAS PARAMETERS (Continued)
50,000 Tire Per Day Model Plant

Operation (Regulatory Alternative)		Flow Rate m^3/sec	Flow Rate (scfm)	Temperature °C	Temperature (°F)	Captured Exhaust Gas VOC Emission Rate kg/day	Captured Exhaust Gas VOC Emission Rate (lb/day)
Undertread cementing	(I)	8.97	(19,000)	20	(68)	2370	(5230)
	(II)	11.80	(25,000)	20	(68)	2530	(5580)
Sidewall cementing	(I)	N/A		20	(68)	N/A	N/A
	(II)	11.72	(25,000)	20	(68)	1645	(3625)
Manual tread end cementing	(I)	16.99	(36,000)	20	(68)	365	(800)
	(II)	19.82	(42,000)	20	(68)	390	(855)
Automatic tread end cementing	(I)	14.63	(31,000)	20	(68)	875	(1935)
	(II)	18.41	(39,000)	20	(68)	935	(2065)
Bead dipping	(I)	9.91	(21,000)	20	(68)	305	(670)
	(II)	13.22	(28,000)	20	(68)	325	(715)
Organic solvent-based green tire spraying	(I)	12.74	(27,000)	20	(68)	5145	(11345)
	(II)[a]	12.74	(27,000)	20	(68)	5490	(12100)

Table 8-8. CAPTURED EXHAUST GAS PARAMETERS (Continued)
50,000 Tire Per Day Model Plant

Operation (Regulatory Alternative)		Flow Rate m^3/sec	Flow Rate (scfm)	Temperature °C	Temperature (°F)	Captured Exhaust Gas VOC Emission Rate kg/day	Captured Exhaust Gas VOC Emission Rate (lb/day)
Water-based green tire spraying	(I)	N/A		20	(68)	N/A	
	(II)	N/A		20	(68)	N/A	
Undertread and manual tread end cementing[b]	(I)	25.96	(55,000)	20	(68)	2735	(6030)
	(II)	31.62	(67,000)	20	(68)	2920	(6435)
Undertread and automatic tread end cementing[b]	(I)	23.60	(50,000)	20	(68)	3250	(7165)
	(II)	30.21	(64,000)	20	(68)	3465	(7640)

Table 8-8. CAPTURED EXHAUST GAS PARAMETERS (Continued)
1 Line Retrofit

Operation (Regulatory Alternative)		Flow Rate		Temperature		Captured Exhaust Gas VOC Emission Rate	
		m^3/sec	(scfm)	°C	(°F)	kg/day	(lb/day)
Undertread cementing	(I)	1.25	(2,700)	20	(68)	355	(785)
	(II)	1.70	(3,600)	20	(68)	380	(835)
Sidewall cementing	(I)	N/A		20	(68)	N/A	N/A
	(II)	1.46	(3,100)	20	(68)	205	(455)
Manual tread end cementing	(I)	2.41	(5,100)	20	(68)	55	(125)
	(II)	2.83	(6,000)	20	(68)	60	(130)
Automatic tread end cementing	(I)	2.12	(4,500)	20	(68)	135	(295)
	(II)	2.60	(5,500)	20	(68)	145	(315)
Bead dipping	(I)	2.45	(5,200)	20	(68)	80	(170)
	(II)	3.21	(6,800)	20	(68)	85	(185)
Organic solvent-based green tire spraying	(I)	1.60	(3,400)	20	(68)	645	(1420)
	(II)[a]	1.60	(3,400)	20	(68)	685	(1510)

Table 8-8. CAPTURED EXHAUST GAS PARAMETERS (Concluded)

1 Line Retrofit

Operation (Regulatory Alternative)		Flow Rate m^3/sec	Flow Rate (scfm)	Temperature °C	Temperature (°F)	Captured Exhaust Gas VOC Emission Rate kg/day	Captured Exhaust Gas VOC Emission Rate (lb/day)
Water-based green	(I)	N/A		20	(68)	N/A	
tire spraying	(II)	N/A		20	(68)	N/A	

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[a] Presented for illustrative purposes only.

[b] Capture components are manifolded into one VOC control component.

in general, be larger than for an afterburner component servicing similar solvent application activities. Further details regarding sizing and capital costs of fans and motors are presented in the GARD Manual.[51]

Exhaust stacks are provided downstream of the fans for dispersion of exhaust gases in the immediate vicinity of the plant. The capital costs of stacks are included for the solvent application facilities under consideration, since these facilities do not have capture components through which exhaust gases are usually ducted to the atmosphere. Stack costs are determined by using GARD Manual prices, which are a function of the weight of 6.3 mm (0.25 in) carbon steel used in fabrication. The weight of carbon steel is in turn related to the stack diameter and stack height. The stack diameter is a function of the stack exit velocity and the average wind velocity (nominally 64 kilometers [40 miles] per hour).[51] Through observations of ceiling heights in several tire plants, the stack height is assumed to be about 15 meters (50 feet).[57-59]

Cooling towers and basins are used to remove heat from cooling water servicing the carbon adsorber's condenser. The capital costs of cooling towers are based on tower cooling capacity (tons), which is a function of the carbon adsorber's steam requirements. Capital costs include the price of the cooling tower, fans, pumps, motors, and installation. Basin area requirements are calculated as a function of cooling tower price. Methodologies used for sizing cooling towers and basins are presented in the GARD Manual.[51]

All capital costs of capture components, appurtenant fans, motors, stacks, and cooling towers are derived from the GARD Manual.[51] All prices are updated to December 1979 values using the Chemical Engineering indices.[63]

Once the flow rates through the model capture components are established, model plant VOC control component costs can be determined. Capital costs of control components are derived from information supplied by vendors of VOC control components. Carbon adsorber units are available for all flow rates involved, whereas direct flame and catalytic afterburner units can only effectively treat up to 19 cubic meters per second [m^3/sec] (40,000 scfm).[38,51,64] In such cases where flow rates exceed 19 m^3/sec, more than one afterburner unit is included in the design. The capital costs of control components for each operation and model plant size are presented in Table 8-9.

8.1.2.1.2 Capital costs of VOC emission reduction systems. December 1979 total installed capital costs are calculated for the different combinations of solvent application facilities, regulatory alternatives, control systems, and model plant sizes. Direct costs include switches, hoods, ducts, fans, motors, stacks, fabrication labor, freight taxes, and installation labor. Indirect capital costs include engineering and contractors fees, field overhead, test runs, parts, and performance testing. No model studies are known to have been performed on VOC emission reduction systems. Thus, capital costs for model studies are not included, as the values could not be determined. The total installed capital costs of the VOC emission reduction systems are summarized in Table 8-10. Capital costs for cooling towers and basins are presented in Table 8-10 as separate values for each model plant, as costs for this equipment are not directly attributed to any single operation.

Comparison of the total installed capital costs shows that model VOC emission reduction systems using thermal afterburners have costs which are generally in the same range as costs for similar systems that employ carbon adsorbers. The capital cost difference for VOC emission reduction systems using carbon adsorbers and direct flame afterburners varies about ±15 percent over the range of exhaust flow rates studied. Emission reduction systems employing carbon adsorbers tend to cost less than systems using direct flame afterburners at flow rates below 4.72 m^3/sec (10,000 scfm). Emission reduction systems using catalytic afterburners exhibit much higher capital costs: in the cases studied, the capital costs for systems employing carbon adsorbers are 15 to 50 percent less than the cost of comparable systems which employ catalytic afterburners; the larger differences in costs between emission reduction systems employing carbon adsorbers and catalytic afterburners are exhibited at lower air flow rates. The capital costs of purchasing and installing the VOC emission reduction equipment

Table 8-9. CONTROL DEVICE COSTS
15,000 Tire Per Day Model Plant

Operation (Regulatory Alternative)		Flow Rate		CONTROL DEVICE COSTS 12/79 $ freight on board (f.o.b.)		
		m^3/sec	(scfm)	Carbon Adsorber	Direct Flame Afterburner	Catalytic Afterburner
Undertread cementing	(I)	3.78	(8,000)	67,000	78,000	137,000
	(II)	5.19	(11,000)	93,000	99,000	167,000
Sidewall cementing	(I)	N/A		N/A	N/A	N/A
	(II)	4.40	(9,300)	78,000	87,000	150,000
Manual tread end cementing	(I)	7.55	(16,000)	136,000	133,000	217,000
	(II)	8.50	(18,000)	153,000	147,000	237,000
Automatic tread end cementing	(I)	6.14	(13,000)	110,000	113,000	187,000
	(II)	8.02	(17,000)	144,000	140,000	227,000
Bead dipping	(I)	5.19	(11,000)	93,000	99,000	167,000
	(II)	6.61	(14,000)	119,000	119,000	197,000
Organic solvent-based green tire spraying	(I)	6.61	(14,000)	119,000	119,000	197,000
	(II)[a]	6.61	(14,000)	119,000	119,000	197,000

Table 8-9. CONTROL DEVICE COSTS (Continued)
15,000 Tire Per Day Model Plant

Operation (Regulatory Alternative)		Flow Rate m^3/sec	Flow Rate (scfm)	CONTROL DEVICE COSTS 12/79 $ freight on board (f.o.b.) Carbon Adsorber	Direct Flame Afterburner	Catalytic Afterburner
Water-based green tire spraying	(I)	N/A		N/A	N/A	N/A
	(II)	N/A		N/A	N/A	N/A
Undertread and manual tread end cementing[b]	(I)	11.33	(21,000)	179,000	168,000	267,000
	(II)	13.69	(29,000)	247,000	223,000	347,000
Undertread and automatic tread end cementing[b]	(I)	9.91	(21,000)	179,000	168,000	267,000
	(II)	13.22	(28,000)	239,000	216,000	337,000

Table 8-9. CONTROL DEVICE COSTS (Continued)
30,000 Tire Per Day Model Plant

Operation (Regulatory Alternative)		Flow Rate m^3/sec	Flow Rate (scfm)	CONTROL DEVICE COSTS 12/79 $ freight on board (f.o.b.) Carbon Adsorber	Direct Flame Afterburner	Catalytic Afterburner
Undertread cementing	(I)	5.19	(11,000)	93,000	99,000	167,000
	(II)	7.08	(15,000)	127,000	126,000	207,000
Sidewall cementing	(I)	N/A		N/A	N/A	N/A
	(II)	7.33	(16,000)	131,000	130,000	212,000
Manual tread end cementing	(I)	9.91	(21,000)	179,000	168,000	267,000
	(II)	11.33	(24,000)	204,000	188,000	297,000
Automatic tread end cementing	(I)	8.50	(18,000)	153,000	147,000	237,000
	(II)	10.86	(23,000)	196,000	181,000	287,000
Bead dipping	(I)	7.55	(16,000)	136,000	133,000	217,000
	(II)	9.91	(21,000)	179,000	167,000	267,000
Organic solvent-based green tire spraying	(I)	8.02	(17,000)	144,000	140,000	227,000
	(II)[a]	8.02	(17,000)	144,000	140,000	227,000

Table 8-9. CONTROL DEVICE COSTS (Continued)
30,000 Tire Per Day Model Plant

Operation (Regulatory Alternative)		Flow Rate m^3/sec	Flow Rate (scfm)	CONTROL DEVICE COSTS 12/79 $ freight on board (f.o.b.) Carbon Adsorber	Direct Flame Afterburner	Catalytic Afterburner
Water-based green tire spraying	(I)	N/A		N/A	N/A	N/A
	(II)	N/A		N/A	N/A	N/A
Undertread and manual tread end cementing[b]	(I)	15.10	(32,000)	273,000	243,000	377,000
	(II)	18.41	(39,000)	333,000	291,000	447,000
Undertread and automatic tread end cementing[b]	(I)	13.69	(29,000)	247,000	223,000	347,000
	(II)	17.94	(38,000)	325,000	284,000	437,000

Table 8-9. CONTROL DEVICE COSTS (Continued)
50,000 Tire Per Day Model Plant

Operation (Regulatory Alternative)		Flow Rate m^3/sec	Flow Rate (scfm)	CONTROL DEVICE COSTS 12/79 $ freight on board (f.o.b.) Carbon Adsorber	Direct Flame Afterburner	Catalytic Afterburner
Undertread cementing	(I)	8.97	(19,000)	161,000	154,000	247,000
	(II)	11.80	(25,000)	213,000	195,000	307,000
Sidewall cementing	(I)	N/A		N/A	N/A	N/A
	(II)	11.72	(25,000)	213,000	195,000	307,000
Manual tread end cementing	(I)	16.99	(36,000)	307,000	271,000	417,000
	(II)	19.82	(42,000)	359,000	312,000	477,000
Automatic tread end cementing	(I)	14.63	(31,000)	265,000	236,000	367,000
	(II)	18.41	(39,000)	333,000	291,000	447,000
Bead dipping	(I)	9.91	(21,000)	179,000	167,000	267,000
	(II)	13.22	(28,000)	239,000	216,000	337,000
Organic solvent-based green tire spraying	(I)	12.74	(27,000)	230,000	209,000	327,000
	(II)[a]	12.74	(27,000)	230,000	209,000	327,000

Table 8-9. CONTROL DEVICE COSTS (Continued)
50,000 Tire Per Day Model Plant

Operation (Regulatory Alternative)		Flow Rate		CONTROL DEVICE COSTS 12/79 $ freight on board (f.o.b.)		
		m^3/sec	(scfm)	Carbon Adsorber	Direct Flame Afterburner	Catalytic Afterburner
Water-based green tire spraying	(I)	N/A		N/A	N/A	N/A
	(II)	N/A		N/A	N/A	N/A
Undertread and manual tread end cementing[b]	(I)	25.96	(55,000)	471,000	401,000	607,000
	(II)	31.62	(67,000)	574,000	484,000	727,000
Undertread and automatic tread end cementing[b]	(I)	23.60	(50,000)	428,000	367,000	557,000
	(II)	30.21	(64,000)	548,000	463,000	697,000

Table 8-9. CONTROL DEVICE COSTS (Continued)
1 Line Retrofit

Operation (Regulatory Alternative)		Flow Rate m^3/sec	(scfm)	CONTROL DEVICE COSTS 12/79 $ freight on board (f.o.b.) Carbon Adsorber	Direct Flame Afterburner	Catalytic Afterburner
Undertread cementing	(I)	1.25	(2,700)	21,000	41,000	83,000
	(II)	1.70	(3,600)	29,000	48,000	93,000
Sidewall cementing	(I)	N/A		N/A	N/A	N/A
	(II)	1.46	(3,100)	25,000	45,000	88,000
Manual tread end cementing	(I)	2.41	(5,100)	42,000	58,000	108,000
	(II)	2.83	(6,000)	50,000	64,000	117,000
Automatic tread end cementing	(I)	2.12	(4,500)	37,000	54,000	102,000
	(II)	2.60	(5,500)	45,000	61,000	112,000
Bead dipping	(I)	2.45	(5,200)	43,000	59,000	109,000
	(II)	3.21	(6,800)	57,000	70,000	125,000
Organic solvent-based green tire spraying	(I)	1.60	(3,400)	27,000	47,000	91,000
	(II)[a]	1.60	(3,400)	27,000	47,000	91,000

Table 8-9. CONTROL DEVICE COSTS (Concluded)
1 Line Retrofit

Operation (Regulatory Alternative)		Flow Rate m^3/sec	Flow Rate (scfm)	CONTROL DEVICE COSTS 12/79 $ freight on board (f.o.b.) Carbon Adsorber	Direct Flame Afterburner	Catalytic Afterburner
Water-based green	(I)	N/A		N/A	N/A	N/A
tire spraying	(II)	N/A		N/A	N/A	N/A

[a] Presented for illustrative purposes only.

[b] Capture components are manifolded into one VOC control component.

Table 8-10. CAPITAL COSTS OF VOC EMISSION REDUCTION SYSTEMS FOR RUBBER TIRE MANUFACTURING MODEL PLANTS
15,000 Tire Per Day Model Plant

			Installed Cost 12/79 dollars x 1000			Installed Cost Attributable to Regulatory Alternative II 12/79 dollars x 1000		
Operation	Regulatory Alternative	Percent Reduction in Emissions	Carbon Adsorber[a]	Direct Flame Afterburner	Catalytic Afterburner	Carbon Adsorber	Direct Flame Afterburner	Catalytic Afterburner
Undertread cementing	(I)	70	380	386	559	-	-	-
	(II)	75	471	465	661	91	79	102
Sidewall cementing	(I)	0	0	0	0	-	-	-
	(II)	75	495	485	664	495	485	664
Manual tread end cementing	(I)	70	600	566	811	-	-	-
	(II)	75	681	637	902	81	71	91
Automatic tread end cementing	(I)	70	561	544	760	-	-	-
	(II)	75	693	656	907	132	112	147
Bead dipping	(I)	70	414	407	603	-	-	-
	(II)	75	516	491	717	102	84	114

Table 8-10. CAPITAL COSTS OF VOC EMISSION REDUCTION SYSTEMS FOR RUBBER TIRE MANUFACTURING MODEL PLANTS (Continued)

15,000 Tire Per Day Model Plant

			Installed Cost 12/79 dollars x 1000			Installed Cost Attributable to Regulatory Alternative II 12/79 dollars x 1000		
Operation	Regulatory Alternative	Percent Reduction in Emissions	Carbon Adsorber[a]	Direct Flame Afterburner	Catalytic Afterburner	Carbon Adsorber	Direct Flame Afterburner	Catalytic Afterburner
Organic solvent-based green tire spraying	(I)	70	534	501	727	-	-	-
	(II)[c]	75	534	501	727	0	0	0
Water-based green tire spraying	(I)	90	5	5	5	-	-	-
	(II)	90	5	5	5	0	0	0
Undertread and manual tread end cementing[b]	(I)	70	865	808	1,094	-	-	-
	(II)	75	1,114	1,022	1,377	249	214	283
Undertread and automatic tread end cementing[b]	(I)	70	877	818	1,104	-	-	-
	(II)	75	1,092	997	1,345	215	179	241

Table 8-10. CAPITAL COSTS OF VOC EMISSION REDUCTION SYSTEMS FOR RUBBER TIRE MANUFACTURING MODEL PLANTS (Continued)
30,000 Tire Per Day Model Plant

			Installed Cost 12/79 dollars x 1000			Installed Cost Attributable to Regulatory Alternative II 12/79 dollars x 1000		
Operation	Regulatory Alternative	Percent Reduction in Emissions	Carbon Adsorber[a]	Direct Flame Afterburner	Catalytic Afterburner	Carbon Adsorber	Direct Flame Afterburner	Catalytic Afterburner
Undertread cementing	(I)	70	511	493	692	-	-	-
	(II)	75	632	595	830	121	102	138
Sidewall cementing	(I)	0	0	0	0	-	-	-
	(II)	-	813	765	995	813	765	995
Manual tread end cementing	(I)	70	780	722	1,008	-	-	-
	(II)	75	891	821	1,133	111	99	125
Automatic tread end cementing	(I)	70	751	707	971	-	-	-
	(II)	75	912	843	1,148	161	136	177
Bead dipping	(I)	70	582	547	793	-	-	-
	(II)	75	767	707	996	185	160	203

Table 8-10. CAPITAL COSTS OF VOC EMISSION REDUCTION SYSTEMS FOR RUBBER TIRE MANUFACTURING MODEL PLANTS (Continued)

30,000 Tire Per Day Model Plant

Operation	Regulatory Alternative	Percent Reduction in Emissions	Installed Cost 12/79 dollars x 1000			Installed Cost Attributable to Regulatory Alternative II 12/79 dollars x 1000		
			Carbon Adsorber[a]	Direct Flame Afterburner	Catalytic Afterburner	Carbon Adsorber	Direct Flame Afterburner	Catalytic Afterburner
Organic solvent-based green tire spraying	(I)	70	662	593	844	-	-	-
	(II)[c]	75	662	593	844	0	0	0
Water-based green tire spraying	(I)	90	7	7	7	-	-	-
	(II)	90	7	7	7	0	0	0
Undertread and manual tread end cementing[b]	(I)	70	1,244	1,121	1,510	-	-	-
	(II)	75	1,431	1,272	1,722	187	151	212
Undertread and automatic tread end cementing[b]	(I)	70	1,181	1,069	1,425	-	-	-
	(II)	75	1,473	1,313	1,753	292	244	328

Table 8-10. CAPITAL COSTS OF VOC EMISSION REDUCTION SYSTEMS FOR RUBBER TIRE MANUFACTURING MODEL PLANTS (Continued)

50,000 Tire Per Day Model Plant

			Installed Cost 12/79 dollars x 1000			Installed Cost Attributable to Regulatory Alternative II 12/79 dollars x 1000		
Operation	Regulatory Alternative	Percent Reduction in Emissions	Carbon Adsorber[a]	Direct Flame Afterburner	Catalytic Afterburner	Carbon Adsorber	Direct Flame Afterburner	Catalytic Afterburner
Undertread cementing	(I)	70	867	794	1,062	-	-	-
	(II)	75	1,052	950	1,273	185	156	211
Sidewall cementing	(I)	0	0	0	0	-	-	-
	(II)	75	1,254	1,165	1,480	1,254	1,165	1,480
Manual tread end cementing	(I)	70	1,303	1,171	1,598	-	-	-
	(II)	75	1,529	1,375	1,846	226	204	248
Automatic tread end cementing	(I)	70	1,268	1,162	1,544	-	-	-
	(II)	75	1,530	1.385	1,835	262	223	291
Bead dipping	(I)	70	756	696	984	-	-	-
	(II)	75	987	895	1,243	231	199	259

Table 8-10. CAPITAL COSTS OF VOC EMISSION REDUCTION SYSTEMS FOR RUBBER TIRE MANUFACTURING MODEL PLANTS (Continued)

50,000 Tire Per Day Model Plant

			Installed Cost 12/79 dollars x 1000			Installed Cost Attributable to Regulatory Alternative II 12/79 dollars x 1000		
Operation	Regulatory Alternative	Percent Reduction in Emissions	Carbon Adsorber[a]	Direct Flame Afterburner	Catalytic Afterburner	Carbon Adsorber	Direct Flame Afterburner	Catalytic Afterburner
Organic solvent-based green tire spraying	(I)	70	1,033	887	1,226	-	-	-
	(II)[c]	75	1,033	887	1,226	0	0	0
Water-based green tire spraying	(I)	90	11	11	11	-	-	-
	(II)	90	11	11	11	0	0	0
Undertread and manual tread end cementing[b]	(I)	70	2,139	1,890	2,476	-	-	-
	(II)	75	2,559	2,225	2,961	420	335	485
Undertread and automatic tread end cementing[b]	(I)	70	2,019	1,774	2,328	-	-	-
	(II)	75	2,488	2,192	2,865	469	418	537

Table 8-10. CAPITAL COSTS OF VOC EMISSION REDUCTION SYSTEMS FOR RUBBER TIRE MANUFACTURING MODEL PLANTS (Continued)
1 Line Retrofit

Operation	Regulatory Alternative	Percent Reduction in Emissions	Installed Cost 12/79 dollars x 1000			Installed Cost Attributable to Regulatory Alternative II 12/79 dollars x 1000		
			Carbon Adsorber[a]	Direct Flame Afterburner	Catalytic Afterburner	Carbon Adsorber	Direct Flame Afterburner	Catalytic Afterburner
Undertread cementing	(I)	70	166	202	331	-	-	-
	(II)	75	203	234	371	37	32	40
Sidewall cementing	(I)	0	0	0	0	-	-	-
	(II)	75	182	217	348	182	217	348
Manual tread end cementing	(I)	70	252	274	426	-	-	-
	(II)	75	286	303	464	34	29	38
Automatic tread end cementing	(I)	70	255	261	407	-	-	-
	(II)	75	272	293	449	17	32	42
Bead dipping	(I)	70	242	264	417	-	-	-
	(II)	75	294	308	476	52	44	59

Table 8-10. CAPITAL COSTS OF VOC EMISSION REDUCTION SYSTEMS FOR RUBBER TIRE MANUFACTURING MODEL PLANTS (Concluded)
1 Line Retrofit

Operation	Regulatory Alternative	Percent Reduction in Emissions	Installed Cost 12/79 dollars x 1000			Installed Cost Attributable to Regulatory Alternative II 12/79 dollars x 1000		
			Carbon Adsorber[a]	Direct Flame Afterburner	Catalytic Afterburner	Carbon Adsorber	Direct Flame Afterburner	Catalytic Afterburner
Organic solvent-based green tire spraying	(I)	70	177	210	344	-	-	-
	(II)[c]	75	177	210	344	0	0	0
Water-based green tire spraying	(I)	90	0	0	0	-	-	-
	(II)	90	0	0	0	0	0	0

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[a] Cost of cooling tower included.

[b] Capture components are manifolded into one VOC control device.

[c] Presented for illustrative purposes only.

which are above the cost of installing equipment to meet the reduction levels suggested by Regulatory Alternative I (total installed costs attributable to Regulatory Alternative II) are presented in Table 8-10. Water-based green tire spray facilities have no capital costs attributable to Regulatory Alternative II as the same water-based green tire sprays used to meet Regulatory Alternative I can be used to meet the VOC emission levels recommended under Regulatory Alternative II. With the exception of green tire spraying activities, the total installed capital costs attributable to Regulatory Alternative II increase with the size of the model plant.

8.1.2.2 Annualized Costs. Annualized costs of the VOC emission reduction systems represent the total annual expenditure required to operate and maintain the equipment. The annualized cost is the sum of annual operating costs and annual capital charges minus annual recovery credits. Operating costs are the day-to-day expenditures necessary to operate the VOC emission reduction system. Capital charges include items associated with owning the equipment. Recovery credits represent the reduction in annual operating costs and annual capital charges due to reclamation of materials or energy by the emission reduction system.

8.1.2.2.1 Operating costs. Operating cost estimates for the VOC emission reduction systems include utilities, operating labor, maintenance, supplies, replacement parts, and waste disposal.

Annual costs for utilities are divided into four areas: electricity, fuel, steam charges, and cooling water charges. The amount of electricity used annually by the VOC emission reduction systems is determined by adding the horsepower requirements of the capture and control components for each facility and placing the sum into the following equation:

$$a = [(0.746b)c]\ 1.1$$

where: a = the amount of kilowatt hours used,
b = horsepower requirements, and
c = annual operating hours.[1-14]

All emission reduction equipment is assumed to operate 6,456 hours per year (24 hours per day for 269 days a year).[1-14] The 1.1 factor included in the above equation represents an adjustment for 10 percent line losses due to inefficiency in power transmission through electrical components of the VOC emission reduction system.[51] Once the kilowatt hour value is determined, it is multiplied by the cost per kilowatt hour ($0.055/kWh).[51]

The amount of gas or oil consumed annually by the afterburner component of the VOC emission reduction system is determined by the following empirical relationship between the annual operating hours, exhaust gas flow rate, fuel credit of the exhaust stream, and the degree of heat recovery available to the control system:

$$F_{ij} = \left([(T_i - T_o)(V_{ij})1.08] - U_{ij}W\right) - \left(T_i - [(T_i - T_o)(1-X) + T_o]1.08\ V_{ij}\right)(6{,}456\text{ hr/yr})$$

where F_{ij} is the annual energy requirement for the VOC emission reduction system in model plant i (i = 15,000, 30,000, or 50,000 tires per day) under Regulatory Alternative j (j = I or II);

T_i is the afterburner temperature in °F;

T_o is the temperature at zero enthalpy (60°F);

V_{ij} represents the gas flow rate through the capture componentin model plant i (i = 15,000, 30,000, or 50,000 tires per day) under Regulatory Alternative j (j = I or II);

U_{ij} is the VOC emission rate (pounds per hour) from the capture component in model plant i under Regulatory Alternative j;

W represents the average heating value of the VOCs in the exhaust stream (10,700 Btu per pound of VOC);[65]

X is the heat recovery efficiency of the control component (45 percent for both afterburner types)[40-44]

The value of 1.08 represents a conversion factor for changing the units of temperature and flow into units of Btus per hour. Exhaust flow rates are dependent on the nature of the solvent application activity involved. The fuel credit of the exhaust stream is a function of the mass of VOCs in the exhaust stream and the heating value of the VOCs. The mass of VOCs in the exhaust stream is dependent on the activity involved; the heating value of the VOCs is derived from the heating value of a representative VOC exhaust stream consisting of 90 percent naphtha, 6 percent n-hexane or n-heptane, 2 percent toluene, 1 percent isopropyl alcohol, and 1 percent other organic solvents.[1-14] Thus the average heating value of the VOCs, with air, is approximately 5.12×10^6 joules per kilogram (10,700 Btu per pound).[65] The output of the mathematical relationship described above is the quantity of joules (Btus) required per year, which when multiplied by the cost per joule (Btu), yields the annual fuel charges. The January 1980 average cost of No. 2 fuel oil is estimated to be \$4.77 per gigajoule (\$5.03 per million Btu);[55] the actual cost per joule value can be as low as 50 percent of this value, depending on the fuel type used and the geographic area in which the fuel is purchased.[66]

Steam requirements for carbon adsorbers includes the quantity of water and heat required to desorb the carbon beds. The price of steam has been obtained through vendor quotations and has been established at \$8.80 per megagram of steam delivered (\$4.00 per 1,000 pounds).[45,46] Steam requirements were extrapolated from the relationship:

$$d_{ij} = g_{ij}hl$$

where d_{ij} represents the annual steam costs for the carbon adsorber VOC control component installed on the facility in model plant i (i = 15,000, 30,000, or 50,000 tires per day) under Regulatory Alternative j (j = I or II);

g_{ij} is the annual quantity of VOCs adsorbed from a facility model plant i under Regulatory Alternative j, which is a function of the quantity of VOCs emitted from solvent application facilities, the capture efficiency suggested by each regulatory alternative, and the removal efficiency of the carbon adsorber;

h represents the quantity of steam required to desorb one pound of VOC (4 kilograms [pounds] of steam per kilogram [pound] of VOCs);[51]

l is the cost of steam (\$11.10 per Mg or \$5.04 per 1,000 lbs of steam).[51]

Cooling water charges were estimated using the equation:

$$k_{ij} = g_{ij}hmp$$

where k_{ij} represents the annual cooling water charges for a carbon adsorber installed on a facility's VOC emission reduction system in model plant i (i = 15,000, 30,000, or 50,000 tires per day) under Regulatory Alternative j (j = I or II);

g_{ij} is the annual quantity of VOCs adsorbed from a facility (pounds) in model plant i under Regulatory Alternative j;

h is the quantity of steam required to desorb one pound of VOC (4 pounds of steam per pound of VOC);[51]

m represents the annual cooling water requirement for the carbon adsorber (12 gallons water/100 pounds of steam);[51]

p is the cost per 1000 gallons of cooling water ($0.116).[51]

Sewerage charges were not calculated as the assumption is made that all water used is recirculated.

Annual operating labor costs are derived from the sum of direct and supervisory labor costs. Direct labor costs are quantified by taking the product of the annual operating hours, the amount of labor per shift allocated to operating the VOC emission reduction system, and the average hourly earnings of rubber production workers. The model plant emission reduction system runs 6,456 hours per year and the average amount of labor allotted to operating the system is 0.5 man-hours.[1-14,51] The U.S. Department of Labor 1978 average hourly earnings per 8-hour shift for rubber tire and tube production workers is used in the analysis: hourly wages are estimated to be $7.82.[52] Supervisory time allotted to operation of the VOC emission reduction system is estimated at 15 percent of the direct labor cost.[51] The assumptions used to calculate annual operating labor costs are summarized in Tables 8-4 through 8-6.

Annual maintenance, replacement, and supply costs represent the labor and material used for upkeep of the emission reduction systems, as well as the supplies required to operate the system. Included in maintenance costs would be the labor and material costs to repair or install motors, fans, switches, and other associated equipment.

Maintenance labor costs are determined from the product of the emission reduction system's annual operating hours (6,456 hours), the amount of labor that is allocated to system maintenance during each shift (0.5 hours), and the average hourly earnings of maintenance workers ($8.60).[1-14,51] Maintenance material costs are estimated to be 100 percent of maintenance labor costs.[51] The replacment cost value for emission reduction systems using carbon adsorbers represents the cost to replace activated carbon and screens; afterbuner costs include the price of new refractory. Methodologies employed to determine the replacement costs of carbon, screens, and refractory are outlined in the GARD Manual.[51] Replacement costs of catalysts for afterburners are calculated from cost information presented in the EPA publication Report of Fuel Requirements, Capital Cost and Operating Expense for Catalytic and Thermal Afterburners.[67] Operating supplies include materials required for cleaning and other janitorial services. Annual operating supply costs are estimated to be 15 percent of the annual maintenance costs.[53] The assumptions used to generate annual maintenance, operating material, and replacement costs are presented in Tables 8-4 through 8-6.

8.1.2.2.2 Capital charges. Annual capital charges for VOC emission reduction equipment comprise the capital recovery factor (CRF), overhead administration costs related to owning the equipment, taxes, and insurance.

The CRF is a function of the discount interest rate and useful equipment life. The relationship is expressed as:

$$CRF = \frac{i\,(1 + i)^n}{(1 + i)^n - 1}$$

where i = the discount interest rate
n = the capital recovery period, in years.

The EPA discount interest estimate used is 10 percent.[51] The capital recovery period, or the economic life of carbon adsorbers and afterburners is 15 years and 10 years, respectively, as the emission reduction systems are not expected to encounter extreme VOC loading or corrosive compounds.[51] Therefore, the CRF for carbon adsorbers (i = 0.10 and n = 15) is 13.1 percent and the CRF for afterbuners (i = 0.10 and n = 10) is 16.3 percent. The CRF is applied to the fixed capital investment, the product being the VOC emission reduction system's annual capital recovery cost.

Annual overhead costs are not charged directly to a particular process, but allocations are made to cover costs of administration, safety, engineering, legal services, medical services, payroll, employee benefits, recreation, and public relations.[68] Annual overhead charges are 80 percent of total annual operating and maintenance labor costs.[51] These assumptions are included in Tables 8-4 through 8-6.

Annual administrative costs associated with owning the emission reduction system and annual permit costs are estimated to be 2 percent of the fixed capital costs.[51] Taxes involved with ownership of the emission reduction system are calculated at 1 percent of the fixed capital investment.[51] Insurance for the emission reduction system was 1 percent of the fixed capital investment.[51]

8.1.2.2.3 Recovery credits. Afterburner recovery credits are based on the amount of heat derived from the VOCs in the exhaust stream and the extent of heat recovery applied to the afterburner. The recovery credits for afterburners are included as part of the empirical relationship involved in the determination of annual afterburner fuel requirements discussed in 8.1.2.2.1. Carbon adsorber recovery credits are expressed as a product of the amount of adsorbed solvent recovered and the market value of the recovered material. The amount of solvent recovered annually is determined by the mass of solvent emitted from a facility, the efficiency of the capture system, and the removal efficiency of the adsorber.

The market value of the recovered material is estimated at $0.31 per liter ($1.17 per gallon). This value is arrived at by taking the percent by weight of each solvent in the exhaust stream and multiplying the percentage by the January 1980 market value.[54] The sum of the values resulted in the weighted average price of the recovered solvent. In cases where the recovered solvent is not used entirely or must be treated before reuse, the value of the recovery credit will be diminished accordingly. A discussion of problems that may be encountered with using recovered solvents is presented in Chapter 4.

The recovery credit allotted to VOC emission reduction systems using carbon adsorbtion is subtracted from the sum of operating costs and capital charges. Certain solvent application operations, such as undertread cementing and organic solvent-based green tire spraying, may experience recovery credits large enough to offset direct operating costs and capital charges. Such cases appear as negative values in the annualized costs presented in Table 8-11. Annualized costs for systems employing carbon adsorbers with no credits given for reuse of recovered solvent are also presented.

8.1.2.2.4 Review of annualized costs. Annualized emission reduction costs are calculated for 216 combinations of model plants and one-line retrofits, solvent application operations, control devices, and regulatory alternatives. Annualized costs for VOC emission reduction systems using carbon adsorbers (without recovery credits) are estimated to be approximately 50 to 65 percent lower than annualized costs for thermal afterburners; carbon adsorbers are expected to incur annualized costs that are about 45 to 60 percent less than catalytic afterburner costs. Lower annualized costs incurred by emission reduction systems employing carbon adsorbers can generally be attributed to lower energy requirements. Annualized costs for VOC emission reduction systems employing catalytic afterburners are generally less than the costs for similar systems that use direct flame afterburners: the exception applies to one-line retrofits having flow rates less than 2.6 m^3/sec (5,500 scfm), as lower fuel requirements due to use of catalytic afterburners are not sufficient to offset their higher capital recovery costs. Undertread cementing activities in 30,000 and 50,000 tire per day model plants and all exhibit annualized emission reduction credits when carbon adsorbers are used and recovery credits are given. Annualized VOC emission reduction costs for all cement and solvent application activities increase with the tire production rate, though in general, economies of scale are exhibited on an annualized emission reduction cost-per-tire basis. Further, the annualized costs incurred by systems manifolding exhaust gas from undertread cementing and tread end cementing facilities into one VOC control device are 2 to 20 percent less than the cost of operating and maintaining separate control device; the

Table 8-11. ANNUALIZED COST DATA FOR REGULATORY ALTERNATIVES I AND II

Model Plant Size Tires/Day	Operation	Regulatory Alternative	VOC Emissions Control Component[a]	Direct Operating Costs, $/yr (12/79)	Annualized Capital Charges, $/yr (12/79)	Annualized Emissions Reduction Costs, $/yr[b]	Incremental Annualized Emissions Reduction Costs, $/yr[b]
15,000	Undertread Cementing	I	CA	40,900	70,900	28,400 (111,800)	-
			TI	191,400	83,900	275,400	-
			CI	137,400	119,000	256,400	-
		II	CA	51,500	86,500	48,600 (138,000)	20,200 (26,200)
			TI	263,300	99,800	363,200	87,800
			CI	193,200	139,700	332,900	76,500
15,000	Sidewall Cementing	I	CA	0	0	0	-
			TI	0	0	0	-
			CI	0	0	0	-
		II	CA	43,300	90,600	76,800 (133,900)	76,800 (133,900)
			TI	229,800	104,000	333,800	333,800
			CI	169,300	140,300	309,600	309,600
15,000	Manual Tread end Cementing	I	CA	63,200	108,600	158,800 (171,800)	-
			TI	406,500	120,400	526,900	-
			CI	306,700	170,100	476,800	-
		II	CA	74,200	122,500	182,800 (196,700)	24,000 (24,900)
			TI	457,000	134,800	591,800	64,900
			CI	345,700	188,500	534,200	57,400
15,000	Automatic Tread end Cementing	I	CA	53,300	101,900	124,100 (155,200)	-
			TI	327,900	115,900	443,800	-
			CI	245,400	159,700	405,100	-
		II	CA	71,900	124,500	163,100 (196,400)	38,700 (41,200)
			TI	426,500	138,600	565,100	121,300
			CI	321,200	189,500	510,700	105,600
15,000	Bead Dipping	I	CA	44,000	76,700	109,900 (120,700)	-
			TI	283,100	88,200	371,300	-
			CI	213,400	127,900	341,300	-
		II	CA	56,400	94,200	139,000 (150,600)	29,100 (29,900)
			TI	357,900	105,200	463,100	91,800
			CI	270,800	151,000	421,800	80,500

Table 8-11. ANNUALIZED COST DATA FOR REGULATORY ALTERNATIVES I AND II (Continued)

Model Plant Size Tires/Day	Operation	Regulatory Alternative	VOC Emissions Control Component[a]	Direct Operating Costs, $/yr (12/79)	Annualized Capital Charges, $/yr (12/79)	Annualized Emissions Reduction Costs, $/yr[b]	Incremental Annualized Emissions Reduction Costs, $/yr[b]
15,000	Organic Solvent-Based Green Tire Spraying	I	CA	73,200	97,300	-8,700 (170,500)	-
			TI	316,800	107,200	424,100	-
			CI	231,700	153,000	384,700	-
		II[c]	CA	74,400	97,300	-20,300 (171,700)	-11,600 (1,200)
			TI	313,300	107,200	420,500	-3,600
			CI	228,700	153,000	381,700	-3,000
15,000	Undertread and Manual Tread End Cementing	I	CA	91,700	154,000	149,400 (245,700)	-
			TI	509,600	169,500	679,100	-
			CI	383,100	227,400	610,500	-
		II	CA	119,300	196,700	212,900 (316,000)	63,500 (70,300)
			TI	707,400	212,800	920,200	241,100
			CI	531,300	284,800	816,100	205,600
15,000	Undertread and Automatic Tread End Cementing	I	CA	93,900	156,100	135,700 (250,000)	-
			TI	505,100	171,500	676,600	-
			CI	378,500	229,500	608,000	-
		II	CA	119,600	193,000	190,100 (312,600)	54,400 (62,600)
			TI	679,500	207,800	887,300	210,700
			CI	506,400	278,300	784,700	176,700

Table 8-11. ANNUALIZED COST DATA FOR REGULATORY ALTERNATIVES I AND II (Continued)

Model Plant Size Tires/Day	Operation	Regulatory Alternative	VOC Emissions Control Component[a]	Direct Operating Costs, $/yr (12/79)	Annualized Capital Charges, $/yr (12/79)	Annualized Emissions Reduction Costs, $/yr[b]	Incremental Annualized Emissions Reduction Costs, $/yr[b]
30,000	Undertread Cementing	I	CA	58,800	93,300	-14,700 (152,100)	-
			TI	243,900	105,600	349,500	-
			CI	173,600	145,900	319,500	-
		II	CA	76,700	114,100	12,200 (190,800)	26,900 (38,700)
			TI	340,700	126,300	467,000	117,500
			CI	245,500	173,900	419,400	99,900
30,000	Sidewall Cementing	I	CA	0	0	0	-
			TI	0	0	0	-
			CI	0	0	0	-
		II	CA	67,000	145,100	98,000 (212,100)	98,000 (212,100)
			TI	346,100	160,800	506,900	508,900
			CI	270,100	207,400	477,500	477,500
30,000	Manual Tread end Cementing	I	CA	85,000	139,500	198,600 (224,500)	-
			TI	530,400	152,000	682,400	-
			CI	404,200	210,000	614,200	-
		II	CA	94,500	158,500	225,300 (253,000)	26,700 (28,500)
			TI	602,900	172,100	775,000	92,600
			CI	454,300	235,300	689,600	75,400
30,000	Automatic Tread end Cementing	I	CA	78,500	134,500	150,700 (213,000)	-
			TI	445,200	149,000	594,200	-
			CI	333,600	202,500	536,100	-
		II	CA	96,200	162,100	191,500 (258,300)	40,800 (45,300)
			TI	566,800	176,600	743,400	149,200
			CI	414,800	238,400	653,200	117,100
30,000	Bead Dipping	I	CA	64,100	105,500	148,000 (169,600)	-
			TI	404,500	116,600	521,000	-
			CI	305,500	166,400	471,900	-
		II	CA	84,700	137,200	198,800 (221,900)	50,800 (52,300)
			TI	527,500	149,000	676,500	155,400
			CI	401,700	207,600	609,300	137,400

Table 8-11. ANNUALIZED COST DATA FOR REGULATORY ALTERNATIVES I AND II (Continued)

Model Plant Size Tires/Day	Operation	Regulatory Alternative	VOC Emissions Control Component[a]	Direct Operating Costs, $/yr (12/79)	Annualized Capital Charges, $/yr (12/79)	Annualized Emissions Reduction Costs, $/yr[b]	Incremental Annualized Emissions Reduction Costs, $/yr[b]
30,000	Organic Solvent-Based Green Tire Spraying	I	CA	104,500	119,200	-133,800 (223,700)	-
			TI	344,500	125,900	470,300	-
			CI	238,200	176,800	414,900	-
		II[c]	CA	107,000	119,200	-157,900 (226,200)	-24,100 (2,500)
			TI	337,900	125,900	463,800	-6,500
			CI	231,600	176,800	408,400	-6,500
30,000	Undertread and Manual Tread End Cementing	I	CA	142,400	219,000	168,800 (361,400)	-
			TI	757,000	232,900	989,900	-
			CI	564,800	311,800	876,600	-
		II	CA	166,800	251,100	211,700 (417,900)	42,900 (56,500)
			TI	927,000	354,700	1,281,700	291,800
			CI	696,500	354,700	1,051,200	174,600
30,000	Undertread and Automatic Tread End Cementing	I	CA	132,300	208,200	111,900 (340,500)	-
			TI	676,800	222,400	899,200	-
			CI	499,000	246,700	745,700	-
		II	CA	170,500	258,300	183,800 (428,800)	71,900 (394,300)
			TI	878,300	271,800	1,150,100	250,900
			CI	666,200	288,800	960,700	215,000

Table 8-11. ANNUALIZED COST DATA FOR REGULATORY ALTERNATIVES I AND II (Continued)

Model Plant Size Tires/Day	Operation	Regulatory Alternative	VOC Emissions Control Component[a]	Direct Operating Costs, $/yr (12/79)	Annualized Capital Charges, $/yr (12/79)	Annualized Emissions Reduction Costs, $/yr[b]	Incremental Annualized Emissions Reduction Costs, $/yr[b]
50,000	Undertread Cementing	I	CA	103,900	154,400	-19,800 (258,300)	-
			TI	419,600	166,600	586,200	-
			CI	297,700	220,900	518,600	-
		II	CA	123,800	186,100	12,300 (309,900)	32,100 (51,600)
			TI	559,200	198,200	757,400	171,200
			CI	404,800	263,700	668,500	149,900
50,000	Sidewall Cementing	I	CA	0	0	0	-
			TI	0	0	0	-
			CI	0	0	0	-
		II	CA	112,700	220,700	143,200 (333,400)	143,200 (333,400)
			TI	581,500	241,800	823,300	823,300
			CI	433,900	305,700	739,500	739,500
50,000	Manual Tread end Cementing	I	CA	142,500	229,100	328,700 (371,600)	-
			TI	894,200	243,000	1,137,200	-
			CI	680,300	329,600	1,009,900	-
		II	CA	166,800	267,900	388,600 (434,700)	59,900 (63,100)
			TI	1,042,200	284,400	1,326,600	189,400
			CI	793,900	379,900	1,173,800	163,900
50,000	Automatic Tread end Cementing	I	CA	123,400	223,100	242,900 (346,600)	-
			TI	757,500	241,200	998,700	-
			CI	570,500	318,700	889,200	-
		II	CA	156,600	268,100	313,500 (424,700)	70,600 (78,100)
			TI	951,500	286,400	1,237,900	239,200
			CI	720,200	377,600	1,097,800	208,600
50,000	Bead Dipping	I	CA	85,900	135,300	185,200 (221,200)	-
			TI	524,400	146,800	671,200	-
			CI	398,200	205,100	603,300	-
		II	CA	110,800	174,900	247,200 (285,700)	62,000 (64,500)
			TI	699,700	187,100	886,800	215,600
			CI	528,000	257,600	785,600	182,300

Table 8-11. ANNUALIZED COST DATA FOR REGULATORY ALTERNATIVES I AND II (Continued)

Model Plant Size Tires/Day	Operation	Regulatory Alternative	VOC Emissions Control Component[a]	Direct Operating Costs, $/yr (12/79)	Annualized Capital Charges, $/yr (12/79)	Annualized Emissions Reduction Costs, $/yr[b]	Incremental Annualized Emissions Reduction Costs, $/yr[b]
50,000	Organic Solvent-Based Green Tire Spraying	I	CA	162,000	182,800	-252,300 (344,800)	-
			TI	532,400	185,500	717,900	-
			CI	367,200	254,200	621,400	-
		II[c]	CA	166,100	182,800	-291,200 (348,900)	-38,900 (4,100)
			TI	521,600	185,500	707,100	-10,800
			CI	356,900	254,200	611,100	-10,300
50,000	Undertread and Manual Tread End Cementing	I	CA	236,300	430,300	287,800 (608,800)	-
			TI	1,297,100	388,800	1,685,900	-
			CI	971,400	507,600	1,479,000	-
		II	CA	245,900	444,600	346,700 (690,500)	58,900 (81,700)
			TI	1,589,600	456,700	2,046,300	360,400
			CI	1,195,500	605,900	1,801,400	322,400
50,000	Undertread and Automatic Tread End Cementing	I	CA	226,100	351,900	197,000 (578,000)	-
			TI	1,153,600	365,300	1,518,900	-
			CI	863,100	477,500	1,340,600	-
		II	CA	280,800	432,400	305,000 (713,200)	108,000 (135,200)
			TI	1,497,000	450,000	1,947,000	428,100
			CI	1,121,900	586,400	1,708,300	367,700

Table 8-11. ANNUALIZED COST DATA FOR REGULATORY ALTERNATIVES I AND II

Model Plant Size Tires/Day	Operation	Regulatory Alternative	VOC Emissions Control Component[a]	Direct Operating Costs, \$/yr (12/79)	Annualized Capital Charges, \$/yr (12/79)	Annualized Emissions Reduction Costs, \$/yr[b]	Incremental Annualized Emissions Reduction Costs, \$/yr[b]
1 Line Retrofit 7,500	Undertread Cementing	I	CA	21,800	34,200	14,300 (56,000)	-
			TI	68,300	46,600	114,900	-
			CI	49,800	72,800	122,600	-
		II	CA	23,800	40,500	19,700 (64,300)	5,400 (8,300)
			TI	91,700	53,100	144,800	29,900
			CI	66,200	80,900	147,100	24,500
1 Line Retrofit 6,250	Sidewall Cementing	I	CA	0	0	0	-
			TI	0	0	0	-
			CI	0	0	0	-
		II	CA	21,000	36,900	34,100 (57,900)	34,100 (57,900)
			TI	83,700	49,700	133,400	133,400
			CI	62,400	76,200	138,600	138,600
1 Line Retrofit 7,500	Manual Tread end Cementing	I	CA	23,500	48,900	65,900 (72,400)	-
			TI	137,200	61,200	198,400	-
			CI	102,200	92,000	194,200	-
		II	CA	26,400	54,700	74,200 (81,100)	8,300 (8,700)
			TI	159,800	67,100	226,900	28,500
			CI	118,600	99,700	218,300	24,100
1 Line Retrofit 7,500	Automatic Tread end Cementing	I	CA	23,100	49,400	56,900 (72,500)	-
			TI	120,300	58,600	178,900	-
			CI	89,000	88,200	177,200	-
		II	CA	24,700	52,300	60,300 (77,000)	3,400 (4,500)
			TI	145,700	65,100	210,800	31,900
			CI	106,500	96,700	203,200	26,000
1 Line Retrofit 12,500	Bead Dipping	I	CA	23,500	47,200	61,600 (70,700)	-
			TI	138,700	59,200	197,900	-
			CI	103,300	90,200	193,500	-
		II	CA	29,100	56,100	75,600 (85,200)	14,000 (14,500)
			TI	178,900	68,100	247,000	49,100
			CI	132,200	102,200	234,400	40,900

Table 8-11. ANNUALIZED COST DATA FOR REGULATORY ALTERNATIVES I AND II (Concluded)

Model Plant Size Tires/Day	Operation	Regulatory Alternative	VOC Emissions Control Component[a]	Direct Operating Costs, \$/yr (12/79)	Annualized Capital Charges, \$/yr (12/79)	Annualized Emissions Reduction Costs, \$/yr[b]	Incremental Annualized Emissions Reduction Costs, \$/yr[b]
1 Line Retrofit 6,250	Organic Solvent-Based Green Tire Spraying	I	CA	26,600	36,000	-12,000 (62,600)	-
			TI	78,500	48,200	126,700	-
			CI	54,800	75,400	130,200	-
		II[c]	CA	27,100	36,000	-16,900 (63,100)	-4,900 (500)
			TI	76,500	48,200	124,700	-2,000
			CI	53,400	75,400	128,800	-1,400

[a] CA, Carbon adsorber.
TI, Direct-flame afterburner.
CI, Catalytic afterburner.

[b] Based on December 1979 values. Negative values indicate credits. Values in parenthesis do not include recovery credits.

[c] Presented for illustrative purpose only.

degree of cost savings is dependent on the model plant size, the control device used, the type of tread end cementing performed, and regulatory alterantive involved. Due to greater energy requirements, the incremental annualized costs of Regulatory Alternative II over Regulatory Alternative I costs are generally higher for systems using afterburners than for emission reduction systems using carbon adsorbers. Annualized and incremental emission reduction costs are presented as Table 8-11.

8.1.2.3 Cost Effectiveness. The cost effectiveness of each VOC emission reduction system is calculated as the quotient of the annualized emission reduction costs and the mass of VOCs removed from an activity's exhaust stream. Therefore, cost effectiveness expresses the cost of removing a unit mass of pollutant. Through the review of cost effectiveness values presented as Table 8-12, it is observed that emission reduction systems which employ carbon adsorbers are more cost effective than either direct flame or catalytic afterburners. Even when no recovery credits are given for reclaimed solvent, the cost effectiveness of carbon adsorbers is, in most cases, superior to that of either type afterburner. For the air flow rate and VOC concentrations studied, emission reduction systems using catalytic afterburners were generally more cost-effective than systems employing direct flame afterburners. Credits realized in the annualized costs are reflected in the cost effectiveness values.

Incremental cost effectiveness values for VOC emission reduction systems are derived from the quotient of the incremental annualized emission reduction costs and the incremental reduction of VOC emissions. Credits received for incremental annualized costs are also reflected in the incremental cost effectiveness values. Incremental cost effectiveness credits are calculated for all emission reduction systems used on organic solvent-based green tire spraying at one-line retrofits, 30,000 tire per day model plants, and 50,000 tire per day model plants. Each organic solvent-based green tire spraying operation receives incremental cost effectiveness credits because in each case, one size of emission reduction system can be used to meet both regulatory alternatives. The retention time of the coated green tire in the spray booth is

Table 8-12. COST-EFFECTIVENESS DATA FOR REGULATORY ALTERNATIVES I AND II

Model Plant Size Tires/Day	Operation	Regulatory Alternative	VOC Emissions Control Component[a]	Model Plant Emissions Reduction Mg/yr (tons/yr)	Incremental Emissions Reduction Mg/yr (tons/yr)	Cost-Effectiveness of System $/Mg ($/ton) of VOCs Removed[b]	Incremental Cost-Effectiveness of System $/Mg ($/ton) of VOCs Removed
15,000	Undertread Cementing	I	CA_c	177.4 (195.5)	-	160 (150)	-
			CA^c	177.4 (195.5)	-	630 (570)	-
			TI	177.4 (195.5)	-	1,550 (1,410)	-
			CI	177.4 (195.5)	-	1,450 (1,310)	-
		II	CA_c	190.0 (209.5)	12.6 (14.0)	260 (230)	1,600 (1,440)
			CA^c	190.0 (209.5)	12.6 (14.0)	730 (660)	2,080 (1,870)
			TI	190.0 (209.5)	12.6 (14.0)	1,910 (1,730)	6,970 (6,270)
			CI	190.0 (209.5)	12.6 (14.0)	1,750 (1,590)	6,070 (5,460)
15,000	Sidewall Cementing	I	CA_c	0 (0)	-	-	-
			CA^c	0 (0)	-	-	-
			TI	0 (0)	-	-	-
			CI	0 (0)	-	-	-
		II	CA_c	121.5 (133.9)	121.5 (133.9)	630 (570)	630 (570)
			CA^c	121.5 (133.9)	121.5 (133.9)	1,100 (1,000)	1,100 (1,000)
			TI	121.5 (133.9)	121.5 (133.9)	2,750 (2,490	2,750 (2,490)
			CI	121.5 (133.9)	121.5 (133.9)	2,550 (2,310)	2,550 (2,310)
15,000	Manual Tread end Cementing	I	CA_c	27.4 (30.2)	-	5,800 (5,260)	-
			CA^c	27.4 (30.2)	-	6,270 (5,690)	-
			TI	27.4 (30.2)	-	19,230 (17,450)	-
			CI	27.4 (30.2)	-	17,400 (15,700)	-
		II	CA_c	29.4 (32.4)	2.0 (2.2)	6,220 (5,640)	12,000 (10,910)
			CA^c	29.4 (32.4)	2.0 (2.2)	6,690 (6,070)	12,450 (11,320)
			TI	29.4 (32.4)	2.0 (2.2)	20,130 (18,220)	32,450 (29,500)
			CI	29.4 (32.4)	2.0 (2.2)	18,170 (16,490)	28,700 (26,090)
15,000	Automatic Tread end Cementing	I	CA_c	66.1 (72.9)	-	1,880 (1,700)	-
			CA^c	66.1 (72.9)	-	2,350 (2,130)	-
			TI	66.1 (72.9)	-	6,710 (6,090)	-
			CI	66.1 (72.9)	-	6,130 (5,560)	-
		II	CA_c	70.8 (78.1)	4.7 (5.2)	2,300 (2,090)	8,230 (7,440)
			CA^c	70.8 (78.1)	4.7 (5.2)	2,770 (2,510)	8,770 (7,920)
			TI	70.8 (78.1)	4.7 (5.2)	7,980 (7,240)	25,810 (23,330)
			CI	70.8 (78.1)	4.7 (5.2)	7,210 (6,540)	22,470 (20,310)

Table 8-12. COST-EFFECTIVENESS DATA FOR REGULATORY ALTERNATIVES I AND II (Continued)

Model Plant Size Tires/Day	Operation	Regulatory Alternative	VOC Emissions Control Component[a]	Model Plant Emissions Reduction Mg/yr (tons/yr)	Incremental Emissions Reduction Mg/yr (tons/yr)	Cost-Effectiveness of System $/Mg ($/ton) of VOCs Removed[b]	Incremental Cost-Effectiveness of System $/Mg ($/ton) of VOCs Removed
15,000	Bead Dipping	I	CA	22.9 (25.2)	-	4,800 (4,360)	-
			CA[c]	22.9 (25.2)	-	5,270 (4,790)	-
			TI	22.9 (25.2)	-	16,210 (14,730)	-
			CI	22.9 (25.2)	-	14,900 (13,540)	-
		II	CA	24.5 (27.0)	1.6 (1.8)	5,670 (5,150)	18,190 (16,170)
			CA[c]	24.5 (27.0)	1.6 (1.8)	6,150 (5,580)	18,690 (16,610)
			TI	24.5 (27.0)	1.6 (1.8)	18,900 (17,150)	57,370 (51,000)
			CI	24.5 (27.0)	1.6 (1.8)	17,220 (15,620)	50,310 (44,720)
15,000	Organic Solvent-Based Green Tire Spraying	I	CA	381.3 (420.3)	-	-20 (-20)	-
			CA[c]	381.3 (420.3)	-	450 (410)	-
			TI	381.3 (420.3)	-	1,110 (1,010)	-
			CI	381.3 (420.3)	-	1,010 (920)	-
		II[d]	CA	408.7 (450.6)	27.4 (30.3)	-50 (-50)	-420 (-380)
			CA[c]	408.7 (450.6)	27.4 (30.3)	420 (380)	45 (40)
			TI	408.7 (450.6)	27.4 (30.3)	1,030 (930)	-130 (-120)
			CI	408.7 (450.6)	27.4 (30.3)	930 (850)	-110 (-100)
15,000	Undertread and Manual Tread End Cementing	I	CA	204.8 (225.7)	-	730 (660)	-
			CA[c]	204.8 (225.7)	-	1,200 (1,090)	-
			TI	204.8 (225.7)	-	3,320 (3,010)	-
			CI	204.8 (225.7)	-	2,980 (2,710)	-
		II	CA	219.4 (241.9)	14.6 (16.2)	970 (880)	4,350 (3,920)
			CA[c]	219.4 (241.9)	14.6 (16.2)	1,440 (1,310)	4,810 (4,340)
			TI	219.4 (241.9)	14.6 (16.2)	4,190 (3,800)	16,510 (14,880)
			CI	219.4 (241.9)	14.6 (16.2)	3,720 (3,370)	14,080 (12,690)
15,000	Undertread and Automatic Tread End Cementing	I	CA	243.5 (268.4)	-	560 (510)	-
			CA[c]	243.5 (268.4)	-	1,030 (930)	-
			TI	243.5 (268.4)	-	2,780 (2,520)	-
			CI	243.5 (268.4)	-	2,500 (2,270)	-
		II	CA	260.9 (287.6)	17.4 (19.2)	730 (660)	3,130 (2,830)
			CA[c]	260.9 (287.6)	17.4 (19.2)	1,200 (1,090)	3,600 (3,260)
			TI	260.9 (287.6)	17.4 (19.2)	3,400 (3,090)	12,110 (10,970)
			CI	260.9 (287.6)	17.4 (19.2)	3,010 (2,730)	10,150 (9,200)

Table 8-12. COST-EFFECTIVENESS DATA FOR REGULATORY ALTERNATIVES I AND II (Continued)

Model Plant Size Tires/Day	Operation	Regulatory Alternative	VOC Emissions Control Component[a]	Model Plant Emissions Reduction Mg/yr (tons/yr)	Incremental Emissions Reduction Mg/yr (tons/yr)	Cost-Effectiveness of System $/Mg ($/ton) of VOCs Removed[b]	Incremental Cost-Effectiveness of System $/Mg ($/ton) of VOCs Removed
30,000	Undertread Cementing	I	CA_c	354.8 (391.1)	-	-40 (-40)	-
			CA^c	354.8 (391.1)	-	430 (390)	-
			TI	354.8 (391.1)	-	990 (890)	-
			CI	354.8 (391.1)	-	900 (820)	-
		II	CA_c	380.1 (419.0)	25.3 (27.9)	30 (30)	1,060 (960)
			CA^c	380.1 (419.0)	25.3 (27.9)	500 (460)	1,530 (1,390)
			TI	380.1 (419.0)	25.3 (27.9)	1,230 (1,110)	4,640 (4,210)
			CI	380.1 (419.0)	25.3 (27.9)	1,100 (1,000)	3,950 (3,580)
30,000	Sidewall Cementing	I	CA_c	0 (0)	-	-	-
			CA^c	0 (0)	-	-	-
			TI	0 (0)	-	-	-
			CI	0 (0)	-	-	-
		II	CA_c	242.9 (267.8)	242.9 (267.8)	400 (370)	400 (370)
			CA^c	242.9 (267.8)	242.9 (267.8)	870 (790)	870 (790)
			TI	242.9 (267.8)	242.9 (267.8)	2,090 (1,890)	2,090 (1,890)
			CI	242.9 (267.8)	242.9 (267.8)	1,970 (1,780)	1,970 (1,780)
30,000	Manual Tread end Cementing	I	CA_c	54.8 (60.4)	-	3,620 (3,290)	-
			CA^c	54.8 (60.4)	-	4,100 (3,700)	-
			TI	54.8 (60.4)	-	12,450 (11,300)	-
			CI	54.8 (60.4)	-	11,210 (10,170)	-
		II	CA_c	58.7 (64.7)	3.9 (4.3)	3,840 (3,480)	6,850 (6,210)
			CA^c	58.7 (64.7)	3.9 (4.3)	4,310 (3,910)	7,310 (6,630)
			TI	58.7 (64.7)	3.9 (4.3)	13,200 (11,980)	23,740 (21,530)
			CI	58.7 (64.7)	3.9 (4.3)	11,750 (10,660)	19,330 (17,530)
30,000	Automatic Tread end Cementing	I	CA_c	132.2 (145.7)	-	1,140 (1,030)	-
			CA^c	132.2 (145.7)	-	1,610 (1,460)	-
			TI	132.2 (145.7)	-	4,490 (4,080)	-
			CI	132.2 (145.7)	-	4,060 (3,680)	-
		II	CA_c	141.6 (156.1)	9.4 (10.4)	1,350 (1,230)	4,340 (3,920)
			CA^c	141.6 (156.1)	9.4 (10.4)	1,820 (1,650)	4,820 (4,360)
			TI	141.6 (156.1)	9.4 (10.4)	5,250 (4,760)	15,870 (14,350)
			CI	141.6 (156.1)	9.4 (10.4)	4,610 (4,180)	12,460 (11,260)

Table 8-12. COST-EFFECTIVENESS DATA FOR REGULATORY ALTERNATIVES I AND II (Continued)

Model Plant Size Tires/Day	Operation	Regulatory Alternative	VOC Emissions Control Component[a]	Model Plant Emissions Reduction Mg/yr (tons/yr)	Incremental Emissions Reduction Mg/yr (tons/yr)	Cost-Effectiveness of System $/Mg ($/ton) of VOCs Removed[b]	Incremental Cost-Effectiveness of System $/Mg ($/ton) of VOCs Removed
30,000	Bead Dipping	I	CA	45.8 (50.4)	-	3,230 (2,940)	-
			CA[c]	45.8 (50.4)	-	3,700 (3,370)	-
			TI	45.8 (50.4)	-	11,380 (10,340)	-
			CI	45.8 (50.4)	-	10,300 (9,360)	-
		II	CA	49.0 (54.0)	3.2 (3.6)	4,060 (3,680)	15,870 (14,110)
			CA[c]	49.0 (54.0)	3.2 (3.6)	4,530 (4,110)	16,340 (14,530)
			TI	49.0 (54.0)	3.2 (3.6)	13,810 (12,530)	48,560 (43,170)
			CI	49.0 (54.0)	3.2 (3.6)	12,430 (11,280)	42,940 (38,170)
30,000	Organic Solvent-Based Green Tire Spraying	I	CA	762.6 (840.6)	-	-180 (-160)	-
			CA[c]	762.6 (840.6)	-	290 (270)	-
			TI	762.6 (840.6)	-	620 (560)	-
			CI	762.6 (840.6)	-	540 (490)	-
		II[d]	CA	817.5 (901.1)	54.9 (60.5)	-190 (-180)	-440 (-400)
			CA[c]	817.5 (901.1)	54.9 (60.5)	280 (250)	50 (40)
			TI	817.5 (901.1)	54.9 (60.5)	570 (510)	-120 (-110)
			CI	817.5 (901.1)	54.9 (60.5)	500 (450)	-120 (-110)
30,000	Undertread and Manual Tread End Cementing	I	CA	409.6 (451.5)	-	410 (370)	-
			CA[c]	409.6 (451.5)	-	1,540 (1,400)	-
			TI	409.6 (451.5)	-	2,420 (2,190)	-
			CI	409.6 (451.5)	-	2,140 (1,940)	-
		II	CA	438.8 (483.7)	29.2 (32.2)	480 (440)	1,470 (1,330)
			CA[c]	438.8 (483.7)	29.2 (32.2)	950 (860)	1,930 (1,750)
			TI	438.8 (483.7)	29.2 (32.2)	2,920 (2,650)	9,990 (9,060)
			CI	438.8 (483.7)	29.2 (32.2)	2,400 (2,170)	5,980 (5,420)
30,000	Undertread and Automatic Tread End Cementing	I	CA	486.9 (536.8)	-	230 (210)	-
			CA[c]	486.9 (536.8)	-	700 (630)	-
			TI	486.9 (536.8)	-	1,850 (1,680)	-
			CI	486.9 (536.8)	-	1,530 (1,390)	-
		II	CA	521.7 (575.1)	34.8 (38.3)	350 (320)	2,070 (1,880)
			CA[c]	521.7 (575.1)	34.8 (38.3)	820 (750)	11,330 (10,300)
			TI	521.7 (575.1)	34.8 (38.3)	2,200 (2,000)	7,210 (6,550)
			CI	521.7 (575.1)	34.8 (38.3)	1,840 (1,670)	6,180 (5,610)

Table 8-12. COST-EFFECTIVENESS DATA FOR REGULATORY ALTERNATIVES I AND II (Continued)

Model Plant Size Tires/Day	Operation	Regulatory Alternative	VOC Emissions Control Component[a]	Model Plant Emissions Reduction Mg/yr (tons/yr)	Incremental Emissions Reduction Mg/yr (tons/yr)	Cost-Effectiveness of System $/Mg ($/ton) of VOCs Removed[b]	Incremental Cost-Effectiveness of System $/Mg ($/ton) of VOCs Removed
50,000	Undertread Cementing	I	CA	591.3 (651.8)	-	-30 (-30)	-
			CA^c	591.3 (651.8)	-	440 (400)	-
			TI	591.3 (651.8)	-	990 (900)	-
			CI	591.3 (651.8)	-	880 (800)	-
		II	CA	633.5 (698.3)	42.2 (46.5)	20 (20)	760 (690)
			CA^c	633.5 (698.3)	42.2 (46.5)	490 (440)	1,220 (1,110)
			TI	633.5 (698.3)	42.2 (46.5)	1,200 (1,080)	4,060 (3,680)
			CI	633.5 (698.3)	42.2 (46.5)	1,060 (960)	3,550 (3,220)
50,000	Sidewall Cementing	I	CA	0 (0)	-	-	-
			CA^c	0 (0)	-	-	-
			TI	0 (0)	-	-	-
			CI	0 (0)	-	-	-
		II	CA	404.8 (446.3)	404.8 (446.3)	350 (320)	350 (320)
			CA^c	404.8 (446.3)	404.8 (446.3)	820 (750)	820 (750)
			TI	404.8 (446.3)	404.8 (446.3)	2,030 (1,840)	2,030 (1,840)
			CI	404.8 (446.3)	404.8 (446.3)	1,830 (1,660)	1,830 (1,660)
50,000	Manual Tread end Cementing	I	CA	91.3 (100.7)	-	3,600 (3,260)	-
			CA^c	91.3 (100.7)	-	4,070 (3,590)	-
			TI	91.3 (100.7)	-	12,460 (11,290)	-
			CI	91.3 (100.7)	-	11,060 (10,030)	-
		II	CA	97.8 (107.9)	6.5 (7.2)	3,970 (3,600)	9,220 (8,320)
			CA^c	97.8 (107.9)	6.5 (7.2)	4,440 (4,030)	9,710 (8,760)
			TI	97.8 (107.9)	6.5 (7.2)	13,560 (12,290)	29,140 (26,300)
			CI	97.8 (107.9)	6.5 (7.2)	12,000 (10,880)	25,220 (22,760)
50,000	Automatic Tread end Cementing	I	CA	220.3 (242.9)	-	1,100 (1,000)	-
			CA^c	220.3 (242.9)	-	1,570 (1,430)	-
			TI	220.3 (242.9)	-	4,530 (4,110)	-
			CI	220.3 (242.9)	-	4,040 (3,660)	-
		II	CA	236.0 (260.2)	15.7 (17.3)	1,330 (1,200)	4,500 (4,080)
			CA^c	236.0 (260.2)	15.7 (17.3)	1,800 (1,630)	4,970 (4,510)
			TI	236.0 (260.2)	15.7 (17.3)	5,250 (4,760)	15,240 (13,830)
			CI	236.0 (260.2)	15.7 (17.3)	4,650 (4,220)	13,290 (12,060)

Table 8-12. COST-EFFECTIVENESS DATA FOR REGULATORY ALTERNATIVES I AND II (Continued)

Model Plant Size Tires/Day	Operation	Regulatory Alternative	VOC Emissions Control Component[a]	Model Plant Emissions Reduction Mg/yr (tons/yr)	Incremental Emissions Reduction Mg/yr (tons/yr)	Cost-Effectiveness of System $/Mg ($/ton) of VOCs Removed[b]	Incremental Cost-Effectiveness of System $/Mg ($/ton) of VOCs Removed
50,000	Bead Dipping	I	CA	76.3 (84.1)	-	2,430 (2,200)	-
			CA^{c}	76.3 (84.1)	-	2,900 (2,630)	-
			TI	76.3 (84.1)	-	8,800 (7,980)	-
			CI	76.3 (84.1)	-	7,910 (7,170)	-
		II	CA	81.7 (90.1)	5.4 (6.0)	3,030 (2,740)	11,480 (10,330)
			CA^{c}	81.7 (90.1)	5.4 (6.0)	3,500 (3,170)	11,940 (10,750)
			TI	81.7 (90.1)	5.4 (6.0)	10,850 (9,840)	39,930 (35,930)
			CI	81.7 (90.1)	5.4 (6.0)	9,620 (8,720)	33,760 (30,380)
50,000	Organic Solvent-Based Green Tire Spraying	I	CA	1,271.0 (1,401.1)	-	-200 (-180)	-
			CA^{c}	1,271.0 (1,401.1)	-	270 (250)	-
			TI	1,271.0 (1,401.1)	-	560 (510)	-
			CI	1,271.0 (1,401.1)	-	490 (440)	-
		II[d]	CA	1,362.5 (1,501.9)	82.1 (90.5)	-210 (-190)	430 (390)
			CA^{c}	1,362.5 (1,501.9)	82.1 (90.5)	260 (230)	40 (40)
			TI	1,362.5 (1,501.9)	82.1 (90.5)	520 (470)	-120 (-110)
			CI	1,362.5 (1,501.9)	82.1 (90.5)	450 (410)	-110 (-100)
50,000	Undertread and Manual Tread End Cementing	I	CA	682.6 (752.4)	-	420 (380)	-
			CA^{c}	682.6 (752.4)	-	890 (810)	-
			TI	682.6 (752.4)	-	2,470 (2,240)	-
			CI	682.6 (752.4)	-	2,170 (1,970)	-
		II	CA	731.3 (806.2)	48.7 (53.8)	510 (460)	1,210 (1,090)
			CA^{c}	731.3 (806.2)	48.7 (53.8)	1,010 (920)	1,680 (1,520)
			TI	731.3 (806.2)	48.7 (53.8)	3,000 (2,720)	7,400 (6,700)
			CI	731.3 (806.2)	48.7 (53.8)	2,640 (2,390)	6,830 (6,190)
50,000	Undertread and Automatic Tread End Cementing	I	CA	811.6 (894.6)	-	240 (220)	-
			CA^{c}	811.6 (894.6)	-	710 (650)	-
			TI	811.6 (894.6)	-	1,870 (1,680)	-
			CI	811.6 (894.6)	-	1,650 (1,500)	-
		II	CA	869.5 (958.5)	57.9 (63.9)	350 (320)	1,870 (1,690)
			CA^{c}	869.5 (958.5)	57.9 (63.9)	820 (740)	2,340 (2,120)
			TI	869.5 (958.5)	57.9 (63.9)	2,240 (2,030)	7,390 (6,700)
			CI	869.5 (958.5)	57.9 (63.9)	1,950 (1,780)	6,350 (5,750)

Table 8-12. COST-EFFECTIVENESS DATA FOR REGULATORY ALTERNATIVES I AND II (Continued)

Model Plant Size Tires/Day	Operation	Regulatory Alternative	VOC Emissions Control Component[a]	Model Plant Emissions Reduction Mg/yr (tons/yr)	Incremental Emissions Reduction Mg/yr (tons/yr)	Cost-Effectiveness of System $/Mg ($/ton) of VOCs Removed[b]	Incremental Cost-Effectiveness of System $/Mg ($/ton) of VOCs Removed
1 Line Retrofit 7,500	Undertread Cementing	I	CA	88.7 (97.8)	-	160 (150)	-
			CA[c]	88.7 (97.8)	-	630 (570)	-
			TI	88.7 (97.8)	-	1,300 (1,180)	-
			CI	88.7 (97.8)	-	1,380 (1,250)	-
		II	CA	95.0 (104.7)	6.3 (6.9)	210 (190)	860 (780)
			CA[c]	95.0 (104.7)	6.3 (6.9)	680 (610)	1,320 (1,200)
			TI	95.0 (104.7)	6.3 (6.9)	1,520 (1,380)	4,750 (4,330)
			CI	95.0 (104.7)	6.3 (6.9)	1,550 (1,410)	3,890 (3,550)
1 Line Retrofit 6,250	Sidewall Cementing	I	CA	0 (0)	-	-	-
			CA[c]	0 (0)	-	-	-
			TI	0 (0)	-	-	-
			CI	0 (0)	-	-	-
		II	CA	50.6 (55.8)	50.6 (55.8)	670 (610)	670 (610)
			CA[c]	50.6 (55.8)	50.6 (55.8)	1,140 (1,040)	1,140 (1,040)
			TI	50.6 (55.8)	50.6 (55.8)	2,640 (2,390)	2,640 (2,390)
			CI	50.6 (55.8)	50.6 (55.8)	2,740 (2,480)	2,740 (2,480)
1 Line Retrofit 7,500	Manual Tread end Cementing	I	CA	13.7 (15.1)	-	4,810 (4,360)	-
			CA[c]	13.7 (15.1)	-	5,290 (4,800)	-
			TI	13.7 (15.1)	-	14,480 (13,140)	-
			CI	13.7 (15.1)	-	14,180 (12,860)	-
		II	CA	14.7 (16.2)	1.0 (1.1)	5,050 (4,580)	8,300 (7,550)
			CA[c]	14.7 (16.2)	1.0 (1.1)	5,520 (5,010)	8,700 (7,910)
			TI	14.7 (16.2)	1.0 (1.1)	15,440 (14,010)	28,500 (25,910)
			CI	14.7 (16.2)	1.0 (1.1)	14,850 (13,480)	24,100 (21,910)
1 Line Retrofit 7,500	Automatic Tread end Cementing	I	CA	33.0 (36.4)	-	1,720 (1,560)	-
			CA[c]	33.0 (36.4)	-	2,200 (1,990)	-
			TI	33.0 (36.4)	-	5,420 (4,920)	-
			CI	33.0 (36.4)	-	5,370 (4,870)	-
		II	CA	35.4 (39.0)	2.4 (2.6)	1,700 (1,550)	1,420 (1,310)
			CA[c]	35.4 (39.0)	2.4 (2.6)	2,180 (1,970)	1,880 (1,730)
			TI	35.4 (39.0)	2.4 (2.6)	5,960 (5,400)	13,290 (12,270)
			CI	35.4 (39.0)	2.4 (2.6)	5,740 (5,210)	10,830 (10,000)

Table 8-12. COST-EFFECTIVENESS DATA FOR REGULATORY ALTERNATIVES I AND II (Concluded)

Model Plant Size Tires/Day	Operation	Regulatory Alternative	VOC Emissions Control Component[a]	Model Plant Emissions Reduction Mg/yr (tons/yr)	Incremental Emissions Reduction Mg/yr (tons/yr)	Cost-Effectiveness of System $/Mg ($/ton) of VOCs Removed[b]	Incremental Cost-Effectiveness of System $/Mg ($/ton) of VOCs Removed
1 Line Retrofit 12,500	Bead Dipping	I	CA	19.1 (21.0)	-	3,220 (2,740)	-
			CA[c]	19.1 (21.0)	-	3,700 (3,140)	-
			TI	19.1 (21.0)	-	10,360 (8,800)	-
			CI	19.1 (21.0)	-	10,130 (8,600)	-
		II	CA	20.4 (22.5)	1.3 (1.5)	3,710 (3,360)	10,770 (9,330)
			CA[c]	20.4 (22.5)	1.3 (1.5)	4,180 (3,790)	11,150 (9,670)
			TI	20.4 (22.5)	1.3 (1.5)	12,110 (10,980)	37,770 (32,730)
			CI	20.4 (22.5)	1.3 (1.5)	11,490 (10,420)	31,460 (27,270)
1 Line Retrofit 6,250	Organic Solvent-Based Green Tire Spraying	I	CA	158.9 (175.1)	-	-80 (-70)	-
			CA[c]	158.9 (175.1)	-	390 (360)	-
			TI	158.9 (175.1)	-	800 (720)	-
			CI	158.9 (175.1)	-	820 (740)	-
		II[d]	CA	170.3 (187.7)	11.4 (12.6)	-100 (-90)	-430 (-390)
			CA[c]	170.3 (187.7)	11.4 (12.6)	370 (340)	40 (40)
			TI	170.3 (187.7)	11.4 (12.6)	730 (660)	-180 (-160)
			CI	170.3 (187.7)	11.4 (12.6)	760 (690)	-120 (-110)

[a] CA, Carbon adsorber.
TI, Direct-flame afterburner.
CI, Catalytic afterburner.

[b] Based on December 1979 values. Negative values indicate credits.

[c] Value does not include recovery credits.

[d] Presented for illustrative purposes only.

critical to the degree of emission reduction achieved, whereas other operations require larger capture/control systems to achieve the additional emission reduction required in moving from Regulatory Alternative I to Regulatory Alternative II. Incremental cost effectiveness values for emission reduction systems employed on applicable solvent application operations are presented along with the cost effectiveness values in Table 8-12.

Curves illustrating the cost-effectiveness of 75-percent efficient retrofit emission reduction systems over a range of uncontrolled VOC emission factors were constructed for undertread cementing, sidewall cementing, automatic tread end cementing, manual tread end cementing, bead cementing, and organic solvent-based green tire spraying operations. Retrofit emission reduction systems were chosen as these devices generally incurred higher operating costs than original-equipment systems. The highest value in the range of uncontrolled VOC emission factors used for developing the curves for each applicable operation represents the highest industry-reported VOC emission factor[1-25]; the lowest value used for each operation was nominally 1 gram of VOC per tire. It was assumed that the air flow rates and capital costs for each operation remained constant over the entire range of VOC emission factors used. The cost curves are presented as Figures 8-1 through 8-6.

8.1.2.4 Base Cost of a Facility. Base costs of facilities vary depending on the model plant's production rate and geographic location. An industry survey indicated that the likely size of a new plant may range from 18,000 to 40,000 tires per day.[69] Land costs ranged from 0.5 to 12 million dollars; the costs depend on the acreage required, geographic location, and possible land improvements. Building costs range from 14 to 110 million dollars. Process equipment costs were estimated to be between 100 and 200 million dollars. The utilization rate was expected to be 85 percent.[69,70] Total projected investment required for the three model plant sizes is derived from the industry survey and presented in Chapter 9. Total capital costs for model tire manufacturing plants, excluding VOC emission reduction systems, are estimated to be approximately $186 million (15,000 tire per day plant),

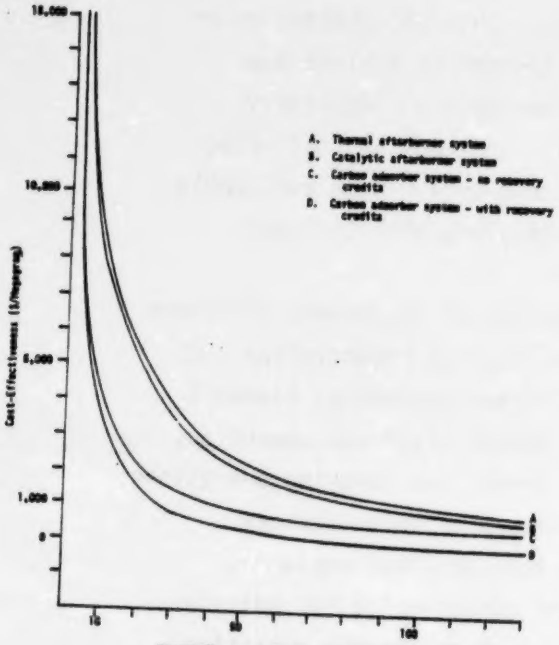

Figure 8-1. Undertread Cementing - Cost-Effectiveness of 75 Percent Efficient VOC Emission Reduction Systems

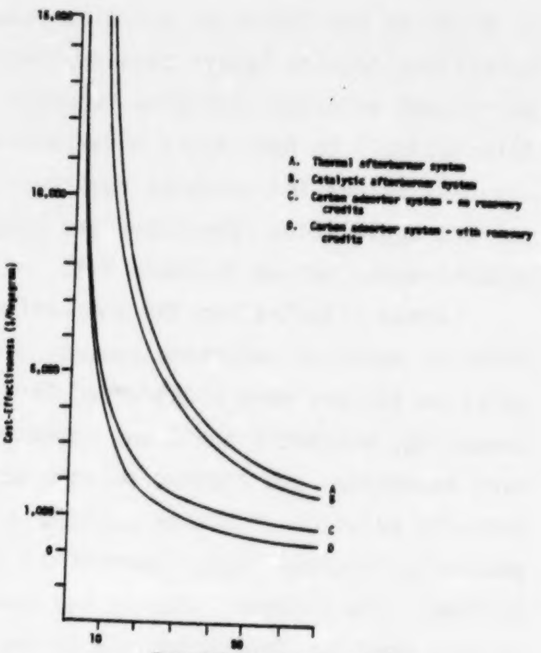

Figure 8-2. Sidewall Cementing - Cost-Effectiveness of 75 Percent Efficient VOC Emission Reduction Systems

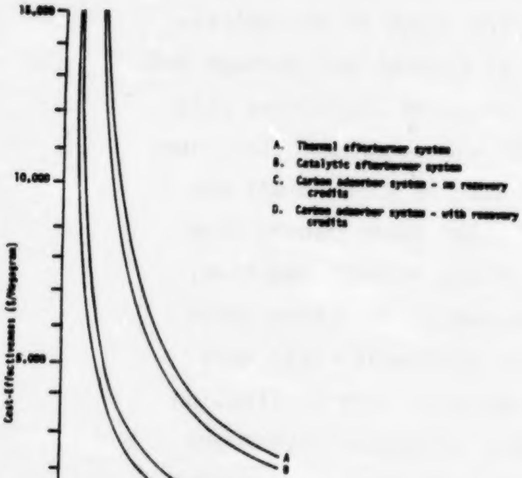

Figure 8-3. Automatic Tread End Cementing - Cost-Effectiveness of 75 Percent Efficient VOC Emission Reduction Systems

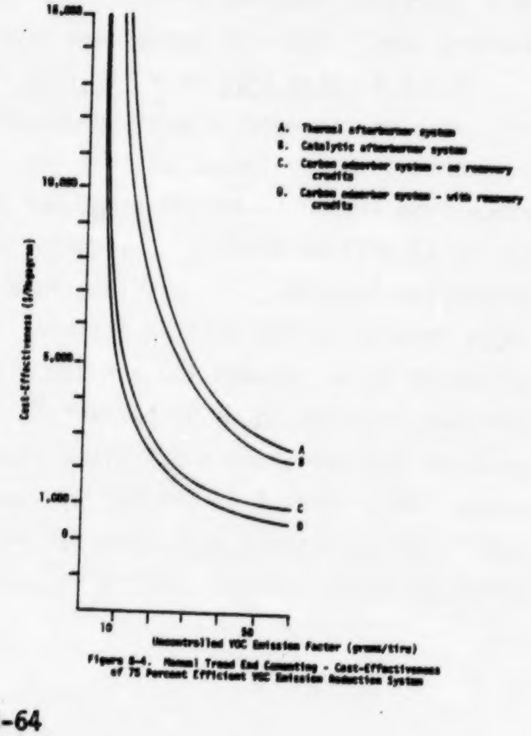

Figure 8-4. Manual Tread End Cementing - Cost-Effectiveness of 75 Percent Efficient VOC Emission Reduction System

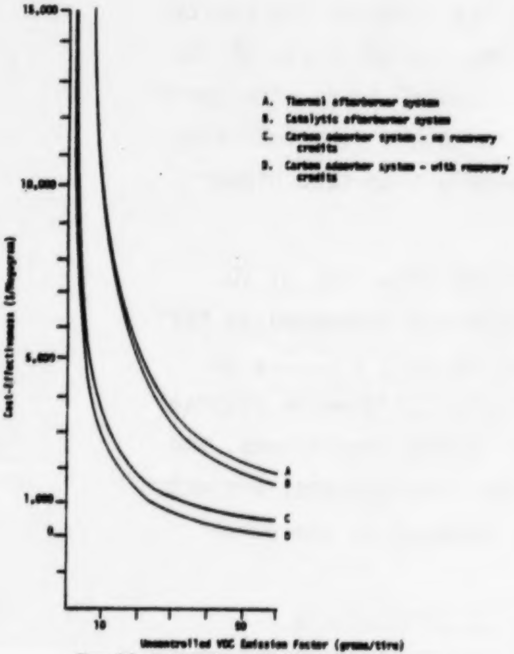

Figure 8-5. Bead Cementing - Cost-Effectiveness of 75 Percent Efficient VOC Emission Reduction Systems

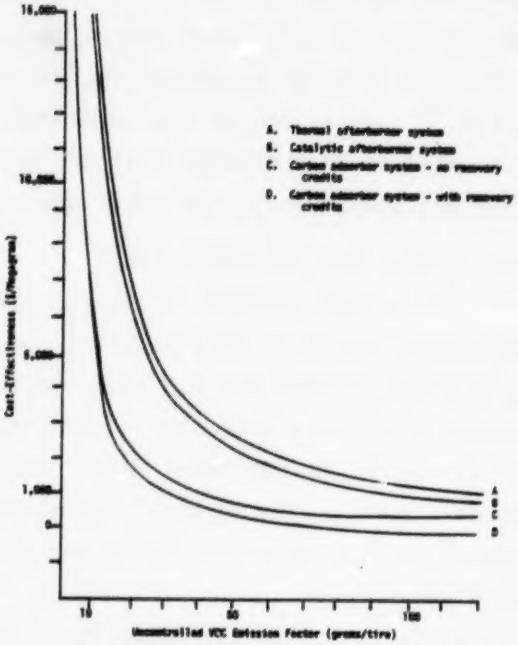

Figure 8-6. Organic Solvent-Based Green Tire Spraying - Cost-Effectiveness of 75 Percent Efficient VOC Emission Reduction

$308 million (30,000 tires per day plant), and $450 million (50,000 tires per day plant). Annualized costs for model plants are projected in Chapter 9 to be about $124 million, $254 million, and $429 million dollars for a 15,000, 30,000, and 50,000 tires per day model plant, respectively.

All costs presented above are in 1979 dollars. The costs include construction of storage areas and employee facilities (cafeteria and restrooms). The average building life was estimated to be 50 years, and the average process equipment life was estimated to be 30 years.[69]

8.1.2.5 Cost Comparison With Industry Analysis. This cost analysis of VOC emission reduction systems that may be used by the tire industry represents the only known in-depth analysis performed as of March 1981. A tire company that has installed a VOC emission reduction system, equipped with a carbon adsorber, as original equipment on one plant's undertread cementing facility has factored the capital costs for emission reduction equipment from the capital costs of the plant.[60] Comparison of the company-supplied capital costs with costs presented in this chapter that are adjusted for plant size indicates that the company-supplied costs are approximately 2 percent higher.

8.2 OTHER COST CONSIDERATIONS

Costs that are not directly associated with reduction of VOC emissions from tire manufacturing are presented and discussed in this section. Included are the costs incurred by the tire industry to comply with water pollution control regulations, solid waste disposal requirements, Occupational Safety and Health (OSHA) regulations, and other air pollution control regulations. Where appropriate, projected annualized VOC emission reduction costs are compared to the other regulatory costs.

8.2.1 Costs Imposed By Water Pollution Control Regulations

Existing and new plants that discharge into surface waters are subject to the effluent limitations specified in their National Pollutant Discharge Elimination System permits, which reflect limits presented in the EPA Effluent Guidelines for Water Quality Standards [40 CFR 428].[71] All tire plants that discharge wastewater containing toxic or nonconservative substances into publicly owned treatment systems are governed by Sections 307, 301(b)(2)(A), and 304(b)(2) of the Federal Water Pollution Control Act [33 U.S.C. 1251, et seq.]; new plants are also subject to the Pretreatment Standards for New Sources [40 CFR 129 and 403].[72-74] Tire plant effluent limitations were discussed in Chapter 7.

Industry-supplied information is used to determine the annualized cost of water pollution control for a model plant which has no VOC emission reduction systems installed. The average annualized cost for water pollution control in plants with no VOC emission reduction systems is estimated to be $0.04 per tire produced.[15-25] Water pollution control costs could not be correlated to plant production rates due to the lack of data. The annualized water pollution control costs for reporting plants are presented as Table 8-13.

Table 8-13. ANNUALIZED WATER POLLUTION CONTROL COSTS INCURRED BY TIRE MANUFACTURERS[15-25]

Plant	Cost per Tire Produced (1979$)
A	0.027
B	0.033
C	0.098
D	0.011
Average	0.042

8.2.2 Costs Imposed By Solid Waste Disposal Requirements

Solid wastes from tire manufacturing are currently disposed of in sanitary landfill, by shipment to reclaiming operations, or recycled for use as raw material in low-quality goods.[58,59,61,75] Sanitary landfills used for solid waste disposal must meet the minimal requirements detailed in the EPA Guidelines for the Thermal Processing of Solid Wastes and for Land Disposal of Solid Wastes [40 CFR 241].[76] Solid waste disposal is further discussed in Chapter 7.

Industry-supplied data are used to determine the annualized cost for solid waste disposal in a model plant employing no VOC emission reduction equipment. The average annualized cost for solid waste disposal is estimated to be $0.04 per tire produced.[15-25] Solid waste disposal costs were compared to percent production rates and found to have poor correlation (r = -0.22). Consequently, annualized per tire solid waste disposal costs are not determined for each size of model plant. The annualized solid waste disposal costs for reporting plants are presented in Table 8-14.

8.2.3 Costs Associated With OSHA Compliance

The cost of compliance with OSHA regulations for the tire manufacturing industry is incurred primarily for ventilation of the workplace. Discussion of OSHA requirements is presented in Chapter 3.

Industry-supplied data indicate that the average annualized cost per tire that can be attributed to OSHA regulations is approximately $0.08. Correlation between OSHA costs and plant production rates is poor (r = -0.64). Consequently, annualized per tire OSHA compliance costs are not determined for each model plant size.[15-25] The average annualized per tire cost for OSHA regulations is presented as Table 8-15.

8.2.4 Costs Associated With Other Air Pollution Control Regulations

Storage and movement of carbon black in a tire plant can result in particulate emissions to the ambient air.[55,59,61] 40 CFR 50 sets the primary and secondary NAAQS for particulates at 60 micrograms per cubic meter for the annual geometric mean and 150 micrograms per cubic meter for one 24-hour period a year.[77] The EPA Regulations on Preparation of Implementation Plans [40 CFR 51] discusses particulate emission reductions achievable with reasonably available control technology.[78] Consequently, the tire industry employs controls to suppress particulate emissions as well as reduce losses of valuable carbon black.[58,59,61]

Industry-supplied information indicates that the average annual cost of particulate control is approximately $0.08 per tire. Correlation of particulate control costs to plant production rates is poor (r = -0.51). Consequently, annualized per tire particulate control costs are not

Table 8-14. ANNUALIZED SOLID WASTE DISPOSAL COSTS INCURRED BY TIRE MANUFACTURERS[15-25]

Plant	Cost per Tire Produced (1979$)
A	0.024
B	0.040
C	0.011
D	0.060
E	0.037
F	0.230
G	0.021
H	0.023
I	0.090
J	0.006
K	0.084
L	0.017
M	0.027
N	0.020
O	0.000
P	0.001
Average	0.043

Table 8-15. ANNUALIZED COSTS INCURRED BY TIRE MANUFACTURERS IN ORDER TO COMPLY WITH OSHA REGULATIONS[15-25]

Plant	Cost per Tire Produced (1979$)
A	0.002
B	0.001
C	0.000
D	0.001
E	0.041
F	0.005
G	0.106
H	0.147
I	0.197
J	0.338
K	0.202
L	0.004
M	0.010
N	0.001
Average	0.075

determined for each model plant size.[15-25] The average annualized per tire cost of particulate control for reporting plants is presented as Table 8-16.

8.2.5 Composite Costs of Environmental Regulatory Requirements

The annualized costs projected to be incurred by the tire industry to meet the requirements of the regulatory alternatives are presented in this subsection and compared to the annualized costs not directly associated with reduction of VOC emissions.

8.2.5.1 Water Pollution Control. The annualized cost of water pollution control that is attributable to a model plant VOC emission reduction system which employs a carbon adsorber control component is estimated by taking the proportion of the total wastewater flow contributed by the adsorber under each regulatory alternative and multiplying the value by the average annualized per tire cost of process and nonprocess wastewater treatment. Annualized water treatment costs attributable to the carbon adsorber effluent under each regulatory alternative are estimated to be less than 0.05 percent of the average total wastewater control costs. Afterburner control components incur no wastewater control costs. The average annualized wastewater control costs for a VOC emission reduction system using a carbon adsorber and the total plant wastewater treatment costs are compared in Table 8-17.

8.2.5.2 Solid Waste Disposal. Activated carbon requirements for the adsorber control components under each regulatory alternative were determined in Chapter 7. The carbon requirements for the adsorbers are converted to a per tire carbon requirement and used to estimate the proportion of solid waste contributed by each regulatory alternative to the plant total. The product of that proportion and the average annualized cost of total plant solid waste disposal per tire produced yields the average annualized cost of solid waste disposal attributable to the regulatory alternatives. Average annualized costs due to disposal of solid wastes from the carbon adsorber control components under each regulatory alternative represent less than 0.05 percent of total solid waste disposal costs. Afterburner control components incur no solid waste disposal costs. Solid waste disposal costs associated with VOC emission reduction are presented and compared to total plant solid waste disposal costs in Table 8-17.

Table 8-16. ANNUALIZED PARTICULATE CONTROL COSTS INCURRED BY TIRE MANUFACTURERS[15-25]

Plant	Cost per Tire Produced (1979$)
A	0.051
B	0.142
C	0.032
D	0.025
E	0.016
F	0.009
G	0.007
H	0.015
I	0.017
J	0.187
K	0.000
L	0.034
M	0.064
N	0.011
O	0.057
P	0.004
Q	0.261
R	0.145
S	0.139
T	0.255
U	0.138
Average	0.077

Table 8-17. PROJECTED ANNUALIZED COSTS OF COMPLIANCE WITH APPLICABLE REGULATORY REQUIREMENTS[15-25]

	Annualized Cost Per Tire Produced (1979$)			
			VOC Requirements - Regulatory Alternative	
Regulatory Requirement	Non-VOC Requirements	VOC Control Component Used	I	II[b]
Water pollution	0.042	Carbon Adsorber	1.9×10^{-5}	1.1×10^{-5}
		Thermal Afterburner	0	0
		Catalytic Afterburner	0	0
Solid waste disposal	0.043	Carbon Adsorber	1.9×10^{-5}	2.1×10^{-5}
		Thermal Afterburner	0	0
		Catalytic Afterburner	0	0
OSHA	0.075	---	-	-
Particulate emissions	0.077	---	-	-
VOC emission reduction[a]	--	Carbon Adsorber	0.038 (0.111)[c]	0.079 (0.124)[c]
		Thermal Afterburner	0.285	0.335
		Catalytic Afterburner	0.265	0.310
TOTAL	0.237	Carbon Adsorber	0.038 (0.111)[c]	0.079 (0.124)[c]
		Thermal Afterburner	0.285	0.335
		Catalytic Afterburner	0.265	0.310

[a] VOC emission reduction is not a regulatory requirement: it is included for comparison to non-VOC regulatory requirement costs.

[b] Regulatory Alternative II does not include the costs for organic solvent-based green tire spraying emission reduction.

[c] Values in parenthesis do not include recovery credits.

8.2.5.3 Comparison of VOC Emission Reduction Costs to Particulate Pollution Control Costs. Annualized costs associated with the regulatory alternatives for the model plants are presented in Section 8.1. When solvent recovery credits are included, VOC emission reduction systems employing carbon adsorber control components are expected to incur annualized costs which are approximately 50 percent less (under Regulatory Alternative I) and 5 percent higher (under Regulatory Alternative II) than the costs incurred by tire manufacturers for particulate (carbon black) pollution controls. When recovery credits are excluded, systems employing carbon adsorbers may have annualized costs that are 45 percent (under Regulatory Alternative I) and 60 percent (under Regulatory Alternative II) higher than the costs for particulate pollution controls. VOC emission reduction systems that use afterburners may have annualized costs which are 245 to 510 percent above the costs to operate and maintain particulate pollution controls, depending on the afterburner type employed and the regulatory alternative involved. The annualized model plant costs for each regulatory alternative and each VOC control component are presented and compared to particulate pollution control costs in Table 8-17.

8.2.5.4 Comparison of Total Costs of Compliance With Applicable Regulatory Requirements. VOC emission reduction systems using carbon adsorbers are expected to increase total annualized costs for compliance with all applicable regulations by approximately 15 percent (under Regulatory Alternative I with recovery credits) to 50 percent (under Regulatory Alternative II with recovery credits), or by $0.04 to $0.12 per tire. Use of afterburner control components is projected to increase total annualized costs for compliance with all regulatory requirements by 110 to 140 percent ($0.24 to $0.33 per tire), depending on the afterburner type employed and the regulatory alternative involved. The average annualized costs per tire for non-VOC related regulatory requirements are totaled and compared to the projected annualized costs of the VOC emission reduction systems in Table 8-17.

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9.0 ECONOMIC IMPACT

9.1 INDUSTRY CHARACTERIZATION

9.1.1 General Profile

9.1.1.1 Industry Structure. Presently, 12 firms manufacture tires in the United States.[1] A company's size is based on its daily production rate of tires, with three size classifications existing within the industry. Goodyear, Firestone, General, B. F. Goodrich, and Uniroyal, dominate the industry and are generally referred to as the "Big Five".[2] In 1979, the "Big Five" and their subsidiaries operated 35 of the 55 domestic tire plants, and manufactured 81 percent of all tires produced domestically. Armstrong, Cooper, Dunlop, and Michelin are intermediate in size and produce in the range of 20,000 to 69,000 tires per day. The Mohawk, Denman, and McCreary firms are categorized as small companies and produce between 500 to 19,000 tires per day. Tire manufacturers, their locations, and 1979 daily production rates are listed in Table 3-1.

9.1.1.2 Ownership. Three domestic firms, Denman, McCreary, and Dunlop, are privately held. Michelin is a privately held French-owned corporation that currently operates three plants within the U.S., with two additional plants scheduled to come on-stream in 1982.[1] Michelin has established a strong reputation in the U.S. market since its development of the radial tire. The remaining firms are publicly owned.

9.1.1.3 Diversification. Company product lines can include nontire-related commodities. The larger firms are the most diversified, producing a multitude of products and manufactured goods: chemicals, plastics, industrial and aerospace products, rubber goods, flooring, packaging film, footwear, and enriched uranium.[3] The smaller companies are typically undiversified firms which primarily market tire-related products.

The major companies are predicted to continue expansion into nontire-related operations. The industry's trend toward diversification has a number of contributing factors:[1,4]

- The declining sales of new automobiles
- The accelerating labor problems associated with tire production
- The increasing number of imported tires
- The capital expenditures associated with operating low-efficiency plants
- The capital costs for construction of new facilities for radial tire production.

In 1978, the General Tire Company led the industry in the percentage of pre-tax profits obtained from nontire-related businesses, receiving 67 percent of its pre-tax profits from diversified activities. Goodyear, the front runner in tire production, has the least diversified product line among the Big Five tire producers. The company has attributed 80 percent of its pre-tax profits to tires and related products over the past 5 years.[5]

The Big Five also produce tire fabricating materials. All produce the synthetic elastomer styrene-butadiene, which is used as a raw material in tire production. Three of the major firms, Goodyear, Firestone, and Uniroyal, produce their own natural rubber.[6] Firestone also produces steel, cord, and beadwire.

Armstrong is virtually undiversified. In addition to tires and tubes, Armstrong produces only wheels and some raw materials.[7] Michelin also limits its manufacturing operations to relatively few product lines.

Small and intermediate sized firms are not diversified beyond the manufacture of tire related products. These firms have product lines which include:

- Tire repair materials - plugs, patches
- Mechanical goods - hoses, belts
- Rubber products - sporting goods, footwear
- Specialty tires - race cars, antique cars, and off-highway vehicles.

The McCreary Tire Company has taken an approach of product-line specialization rather than product-line diversification. Its production is aimed toward specialty tire markets.[8]

9.1.1.4 Market Concentration. Tires are described and categorized according to:

- Type of construction (bias-ply, bias-belted, or radial)
- Vehicle type (passenger car, truck, farm equipment, off-the-road, other)
- Market (original equipment or replacement).

The extent of industry concentration is much greater in the original equipment market than in the replacement market. In 1979, Michelin and the Big Five supplied automobile manufacturers with approximately 61.2 million tires, representing 100 percent of the original equipment (O.E.) market share.[1] During the same year, these same six firms and their subsidiaries sold only 45.2 percent of all passenger tires sold in the replacement market under their own names. Table 9-1 shows the distribution of original equipment shares with respect to the firms. Table 9-2 depicts replacement market shares for passenger car tires by brand name.

9.1.1.5 Raw Materials. The tire industry is the leading consumer of natural and synthetic rubbers in the U.S. Raw materials used to produce tires and rubber related goods include, but are not limited to: synthetic rubber, natural rubber, synthetic fibers, steel, wire, carbon black and rubber chemicals. In 1978 synthetic rubber accounted for approximately 76 percent of all new rubber consumed in the U.S. Styrene-butadiene rubber captured 58 percent of the synthetic rubber market in 1978.[5] Synthetic rubbers other than styrene-butadiene include: polybutadiene, butyl, ethylene-propylene, polychloroprene, nitrile and polyisoprene. These compounds are used more selectively in special tire or rubber applications.

Presently, a higher ratio of natural rubber to synthetic rubber is being utilized in tire fabrication than was used 5 years ago. This increase in the use of natural rubber in tire production is associated with the increase in production of radial tires. Rubber composition of the average radial tire is 5.5 pounds of natural rubber and 6 pounds of synthetic rubber. The typical bias-ply tire uses 8 pounds of synthetic rubber and 2 pounds of natural rubber.[5]

Prices for synthetic rubber fluctuate over a wider range than the prices of natural rubber. Spiraling costs for oil and natural gas are directly

Table 9-1. ESTIMATED SHARES OF ORIGINAL EQUIPMENT MARKET (1979)[a]

Goodyear	27.8%
Uniroyal	24.6%
Firestone	22.6%
General	13.0%
Goodrich	9.5%
Michelin	2.5%
	100.0%

[a] Reference 1.

Table 9-2. **BRAND SHARES OF REPLACEMENT PASSENGER TIRE MARKET**[a]

Goodyear	14.0%
Firestone	10.5%
Sears	10.0%
Michelin	5.0%
Wards	5.0%
B. F. Goodrich	4.5%
Kelly-Springfield	3.0%
K-Mart	3.0%
Atlas	3.0%
Uniroyal	3.0%
Penny's	3.0%
General	3.0%
Dunlop	3.0%
Dayton	2.2%
Delta	1.5%
Copper	1.3%
Armstrong	1.2%
Remington	1.0%
Multi-Mile	1.0%
Hercules	1.0%
Others	20.8%

[a] Reference 1.

responsible for the higher price of synthetic rubber products, which are produced from these resources. Tire producers have been faced with rising costs for raw materials since the oil embargo of 1973.[9] As a result, the cost increases incurred by the industry's purchase of raw materials are passed on to the consumer.

9.1.2 Industry Trends

9.1.2.1 Demand Determinants. In 1979, passenger and truck tire shipments totaled to 228 million units, as shown in Table 9-3.[1] Estimates of tire shipments in 1979 varied according to sources from 215 million tires to 237 million tires.[3,5] An increasing volume of tires was shipped annually between 1975 and 1978, although each year the growth in annual shipments was declining. Fewer tires were shipped in 1979 than were shipped in 1978, reflected by an 8 percent decrease in shipments. Tire manufacturers' combined profits in 1979 fell approximately 21 percent from those in 1978, reaching the lowest level since 1971.[3] Production slow downs and decreased profit margins are attributed to higher direct decline in automobile travel, and the longer life-time of radial tires.[10]

9.1.2.1.1 Replacement market. Passenger tires are the dominant type of tire sold in the replacement market. In 1979, 72.6 percent of all passenger tires shipped were in the replacement market, while 81.6 percent of all tire shipments were passenger tires. Passenger tires shipped in the replacement market represented 59.2 percent of all tire shipments in 1979. Demand for the passenger tire in the replacement market declined about 8.2 percent between 1978 and 1979, exemplified by shipment figures of 147 million units in 1978 and 135 million units in 1979. The increased use of radial tires and their extended durability and lifetime have contributed to the declining need for replacement tires. Demand for replacement tires is also influenced by the consumer's disposable income and tire preference. In 1980, over 50 percent of passenger tires shipped to the replacement market are predicted to be radials.[1]

9.1.2.1.2 Original equipment market. In 1979, the original equipment market received 26.8 percent of all tire shipments. Passenger tires are the major type of tire supplied to the original equipment market, capturing 83 percent of the market share; while truck tires represent only 17 percent of all tires shipped to the original equipment market. A decline in domestic

Table 9-3. INDUSTRY TREND[e]
(millions)

	1975	1976	1977	1978	1979
Passenger Tires					
Replacement	129	137	139	147.0	135
OE	40	50	58	56.5	51
Total	169	187	197	203.5[a]	186[c]
Truck Tires					
Replacement	21.4	23.4	28.5	32[b]	31.8
OE	8.3	9.2	11.2	12	10.2
Total	29.7	32.6	39.7	44	42.0[d]
Total Tires	198.7	219.6	236.7	247.5	228.0

[a] Includes 12 million imports.

[b] Includes 3.1 million imports.

[c] Includes 14.3 million imports both captive and noncaptive.

[d] Includes 5 million imports both captive and noncaptive.

[e] Reference 1.

car production has adversely affected the original equipment market, as the demand for tires in this market is based on the demand for new cars. Between 1978 and 1979, shipments to this market decreased approximately 10 percent, from 68.5 million to 61.2 million tires.

The Big Five and Michelin supply 100 percent of the tires required in original equipment market. As shown in Table 9-1, Goodyear is the largest supplier of tires for new cars, with an estimated 27.8 percent of the market share. Goodyear supplies Chrysler and American Motors with over half of their tire needs, as well as roughly 22 percent of both Ford and General Motor's tire requirements. Uniroyal has captured 24.6 percent of the original equipment market, primarily due to the large supply commitment made to General Motors.

Firestone is the largest single tire supplier to the Ford Motor Company and is ranked third among original equipment suppliers, having 22.6 percent of the market share. General, Goodrich, and Michelin complete the list of tire suppliers to the original equipment market.

Radial tires are expected to be installed on 80 percent of all new cars assembled in 1980, as seen in Table 9-4. In 1972, only 5 percent of all new cars were equipped with radial tires. In 1979, radials accounted for 63.2 percent of all tires shipped in the original equipment market.

9.1.2.1.3 Imports and Foreign Producers. Tire imports made a minimal contribution to domestic tire supplies until the late 1960's.[10] In recent years, tire imports have increased steadily, as seen in Table 9-5.[11] The Department of Commerce estimated that in 1978, 15 percent of the tire market was composed of imports.[10] Some analysts have attributed the growth of imports to:[12]

- The high quality of imported radial tires
- A lag of innovation and production on behalf of U.S. firms
- The U.S. labor strike of 1976 lowering domestic inventories.

Sales of tires produced by foreign-owned companies are expected to rise when the new Michelin plants begin operation. Michelin's production increase could intensify price and market competition.[5]

9.1.2.1.4 Exports. Export levels peaked in 1974 and 1975, and subsequently declined.[13] The industry's labor strike accounted for decreased

Table 9-4. PASSENGER TIRE SHIPMENTS BY MARKET AND TIRE CONTRUCTION FOR 1979[a]

	Bias	Bias-Belt	Radial	Total
Original Equipment	7.7	4.6	38.7	51
Replacement	44.6	25.7	64.7	135
Total	52.3	30.3	103.4	186
% of Total	28.1	16.3	55.6	

TREND FOR PASSENGER TIRES

By Percent of Market Shares and Tire Construction

	Bias	Bias-Belt	Radial
Original Equipment			
1980	14	6	80
1979	15	9	76
1978	13	18	69
1977	10	22	68
Replacement			
1980	30	17	53
1979	33	19	48
1978	35	23	42
1977	36	26	38

[a]Reference 1.

Table 9-5. TIRE EXPORTS AND IMPORTS
(000 tires)

Year	Exports[a]	Imports[b,c]
1968	2,518	N/A
1969	2,364	N/A
1970	1,531	5,300
1971	1,589	6,800
1972	2,127	8,700
1973	4,393	9,500
1974	9,229	10,400
1975	6,124	9,600
1976	4,784	14,600
1977	5,390	15,800

[a] Reference 13.

[b] Reference 11.

[c] Consisting of import plus Michelin shipments. Since Michelin's Spartanburg plant began operating in the early third quarter, 1976, and Greenville plant began operating in the early second quarter, 1975, the estimates for 1975 and 1976 are overestimates. The 1977 estimate does not include Michelin sales to the original equipment market. In addition, the import estimates are for truck and passenger tires only.

exports in 1976 because the domestic demand for tires had to be supplied by existing inventories.

In 1977, the value of export shipments was $310 million, approximately 29 percent of the $1.1 billion value of import shipments.[10] Tire exports contributed to only a minor share of 1977 domestic tire production and represented 3.6 percent of the total dollar value for domestic shipments.

9.1.2.2 Tire Prices. Goodyear and Firestone have generally led price increases among the tire producing firms. However, other companies (Uniroyal and Armstrong) have initiated industrywide price increases. The industry is often involved in a cost-price strategy aimed at capturing larger market shares. Price cutting may occur in response to excess capacity, poor sales or competition. Rising costs for raw materials and labor incurred by the tire industry initiated four separate price increases followed by discounting in 1979. The list price of a replacement tire was raised by 19 percent as a result of the increased production costs.[14]

The average price paid for a tire has increased by more than 40 percent in the last 10 years. The most dramatic increase occurred between 1973 and 1974 when the price rose by 16 percent. Table 9-6 lists the tire price index for years 1968 through 1977 and 1978 median retail tire prices.[15,16]

9.1.2.3 Expansions and Capacities. The tire industry expanded rapidly during the 1960's followed by a slowdown in the early seventies. Plant expansions since 1972 have been to increase production of radial or non-passenger tires.[14,17] A deteriorating business climate during the late 1970's has forced numerous plant closures. Presently, the tire industry is experiencing a deep recession.[14] Current plant operations are estimated to be functioning at 80 percent of capacity based on a 5-day work week,[8] while in 1978, the industry was estimated to have utilized 85 to 90 percent of total capacity.[18] Twenty individual plant closures have occurred since 1976 (refer to Table 3-2 in Chapter 3). Eight plant closures during the last 2 years have cut the industry's production capacity by 9 percent.[8] Additional plant closures have recently been announced by Firestone, Uniroyal, and Armstrong. Firestone and its subsidiaries closed five tire plants in November 1980: Dayton and Barberton, Ohio; Los Angeles and Salinas, California; and Pottstown, Pennsylvania.[19] Uniroyal announced in January 1980, that it would be closing plants in Detroit, Michigan, and Chicopee Falls,

Table 9-6. TIRE PRICE INDICES (1968-1978) AND CURRENT RETAIL PRICES[a]

		Passenger Cars				
Year	Overall	Bias Ply	Belted-Bias	Radial	Truck	Tractor
1968	102.8	-	-	-	-	-
1969	102.3	-	-	-	-	-
1970	109.0	-	-	-	-	-
1971	109.2	-	-	-	-	-
1972	109.2	-	-	-	111.3	114.4
1973	111.4	-	-	-	115.7	117.9
1974	133.4	-	-	-	141.6	147.4
1975	148.5	142.1	104.1*	105.8*	155.4	166.9
1976	161.5	153.3	112.3*	113.6*	172.8	182.8
1977	169.3	165.5	117.5	117.4*	181.7	194.6
June 1978	179.3	-	-	-	-	-

1967 = 100 unless otherwise specified.

*December 1974 = 100.

MEDIAN TIRE PRICES[b]

Year	Bias	Bias-Belted	Radial
1979	37.57	44.94	69.87
1978	32.50	47.50	62.50
1977	32.50	42.50	62.50
1976	29.81	37.02	58.48

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[a] References 15 and 16.

[b] Reference 1.

Massachussetts,[20] while Armstrong has closed its West Haven, Connecticut plant. The impact of industry's production decline is most evident in Akron and Los Angeles, cities once considered as the nation's first and second largest tire producers. After the announced closings are completed, not a single passenger tire will be produced in either Akron or Los Angeles.[21] Over-capacity for bias-belt production and outdated facilities that were built in the early 1900's have contributed to plant closures.[20] Experts cite the closing of older plants as "one of the penalties of progress."[21]

The industry has constructed new facilities and consolidated older, less efficient plants to accommodate for the production of radial tires. Capital expenditures for the rubber industry in 1979 were estimated to be $2.05 billion, up 17 percent from 1978. This increase in capital expenditures reflects the industry's commitment to diversification, and other markets where the business outlook and growth potential are more favorable.[5]

9.1.3 Industry Growth and Future Capacity Requirements

The market for passenger tires can be discussed in terms of two distinct segments, that is, the original equipment market and the replacement market. Since to a certain extent market and demand conditions affect these two segments differently, the potential growth of each segment should be analyzed separately.

The strength of the original equipment market is virtually entirely dependent upon the volume production of new automobiles. While year-to-year fluctuations in auto production have been observed to be as wide as 20 percent, one manufacturer has estimated the long-term (1979-87) growth rate of United States production as an average annual rate of 2 percent.[5]

With regard to tires sold in the replacement market, several factors have combined to indicate slower growth in this area. Specifically, the increasing popularity of higher mileage radial tires, along with the decline in overall driving rate, due to increased gasoline prices, has affected the frequency of tire replacement. Most projections indicate that the growth in demand for replacement tires should approximate 1 percent per year into the mid-1980's.[5]

While the aggregate growth rates for original equipment and replacement market tires are low, it has been projected that radial tires will account for increasingly larger portions of both markets up to 1985. It has been estimated that in the original equipment market the radial portion will increase from 69 percent in 1978,[1] to 85 percent in 1985.[22,23] In the replacement tire market the demand for radials has been projected to increase from 42 percent in 1978[1] to 60 percent in 1985.[22,23] The growth in demand for radial tires, along with the economic and technical difficulties of converting bias tire plants to radial tire production,[14,24] indicate the need for several new radial tire plants over the forecast period (1981-85). The observation that new plants will be constructed for radial tire production, has been supported by industry representatives.[25]

The needed additions to radial tire productive capacity, in terms of new plants, have been estimated as described below. It has been assumed that no portion of the existing radial tire productive capacity will require replacement over the forecast period, due to its relatively recent installation (i.e., first commercial radial produced in 1965),[21] and projected life of 30 years.[25] The projections of new plant requirements are based upon the estimation of several key variables including:

- Total passenger tire demand (1985)
- Total radial tire demand (1978)
- Total radial tire demand (1985)
- Total radial tire capacity (1978)
- Total radial tire capacity (1985).

New additions to capacity have been estimated through the following procedure.

(1) Estimation of total passenger tire demand (1985). Total passenger tire demand (1985) has been estimated through observation of total 1978 passenger tire shipments (as an approximate of sales), in terms of both original equipment and replacement tires, and applying the growth rates in both market segments as noted above. In 1978 total (including exports) passenger tire shipments amounted to 193.9 million, of which approximately 56 million were original equipment and 137.9 million were replacements.[5] According to the growth rates noted above 1985 demand would require 64.4 million [i.e., 56 x $(1.02)^7$] original equipment tires and 147.6 million [i.e., 137.9 x $(1.01)^7$] replacement tires.

(2) Estimation of total radial tire demand (1978). As noted above, radial tires in 1978 accounted for 69 percent of the original equipment market and 42 percent of the replacement market. According to these percentages the total demand levels noted in (1) above, can be expressed in terms of radial tires. Specifically, in the 1978 original equipment market, radial sales amounted to 38.6 million (i.e., 56 x .69) and replacement tires were about 57.9 million (i.e., 137.9 x .42). Total 1978 radial demand is therefore estimated to be 96.5 million tires.

(3) Estimation of total radial tire demand (1985). In 1985, radial tires should account for 85 and 60 percent of the original equipment and replacement markets, respectively. Therefore, 1985 radial tire demand can be estimated as 54.7 million (i.e., 64.4 x .85) original equipment and 88.6 million (i.e., 147.6 x .60) replacement radials. Total 1985 radial demand is therefore estimated as 143.3 million tires.

(4) Estimation of total radial tire capacity (1978). The estimation of total 1978 radial tire capacity is based on the assumption that radial tire capacity utilization for that year can be approximated by industry capacity utilization rates, which for 1978 were about 91 percent.[5] Accordingly, total 1978 radial tire capacity is estimated as 106 million (i.e., 96.5/.91).

(5) Estimation of total required radial tire capacity (1985). The estimation of total required radial tire capacity is based on a capacity utilization rate of 85 percent. This rate was determined to be typical of passenger tire utilization rates since it represents the average capacity utilization[5] of such facilities over the six years 1973-78, approximately one complete business cycle. Assuming future radial tire capacity is used at a rate of 85 percent, the total radial tire capacity needed in 1985 would be 168.6 million (i.e., 143.3/.85) tires.

Total required additions to radial tire capacity (1978-85) can therefore be approximated as required 1985 capacity (168.6 million) less 1978 capacity (106 million) or 62.6 million radial tires. Assuming this need can be met through equal annual additions to capacity, each annual increment would need to add 8.9 million (i.e., 62.6/7 years) tires. However, since the additions to capacity required for 1979 and 1980 should, theoretically, have already been made, the net additions for the forecast period 1981-85, are 44.5 million (i.e., 8.9 x 5 years) radial tires.

Several assumptions have been made in the determination of the new capacity requirements noted above, and to the extent those assumptions may prove invalid, the conclusions as presented will be affected. The assumptions include:

- The import/export levels over the forecast period will remain constant at 1978 proportions,
- Radial tire capacity utilization will, over the forecast period, be 85 percent,
- Additions to radial tire capacity will be made in equal annual increments, and
- Growth rates for original equipment and replacement market radial tires will be consistent with those sources cited.

The addition of radial tire productive capacity of 44.5 million tires per year could be made in a number of ways including the construction of new plants, or through the retrofit of existing tire production lines. The construction of new plants would, given the capacity requirements noted above, require either 3 large, 5 medium, or 9 small plants. Such requirements are based upon 269 operating days per year and capacities of 58,825, 35,300, and 17,650 TPD for the large, medium, and small plants, respectively.

If capacity additions are made through the retrofit of existing lines, a total of 73 retrofits would be required, assuming capacity utilization of 85 percent and output of 6,250 TPD for sidewall cementing lines, 7,500 TPD for tread end and undertread cementing lines, and 12,500 TPD for bead dipping lines. In terms of specific lines, 23 sidewall cementing lines, 19 of both tread end and undertread cementing lines, and 12 bead dipping lines would be required.

9.2 ECONOMIC IMPACT ANALYSIS

9.2.1 Introduction and Summary

In the sections which follow, the economic impacts of the regulatory alternatives are detailed. Economic impacts are discussed in terms of the potential price, profitability, and capital availability impacts of each alternative.

With regard to maximum tire price increases, the use of the most economical VOC control systems could, in the worst case, increase the wholesale price of radial tires by .44 percent. This implies a price increase of 15 cents for a tire which wholesales for $35.[26]

In the event NSPS costs are not passed to consumers in the form of price increases, but instead are absorbed by tire manufacturers, the estimated profitability of new facilities would decline, in the worst case, from a 5.00 percent return on investment (ROI) to 4.78 ROI. The determination of profitability reductions are explained in Section 9.2.3.3.

These conclusions are based upon observations of current capital requirements for investment in new tire manufacturing plants, the growth in demand for radial tires, as well as the current market structure and competitive nature of the industry. Specific estimates with regard to price and profitability impacts, have been made by assessing the expected responses of individual model plants to the capital control and annualized costs summarized in Chapter 8.

9.2.2 Financial Profile and Market Structure

9.2.2.1 Financial Profile of the Industry. Several factors have contributed to the current depressed profit levels in the rubber tire industry. Gasoline shortages and rapidly increasing gasoline prices have served to impact the growth in demand for new domestically produced automobiles (see Section 9.1.3) as well as to restrict the use of existing autos. The slump in new car sales has affected the production of tires for the original equipment market, while the replacement market has felt the impact of reduced driving.[27] In the face of sagging demand, the industry has experienced extraordinary input price pressure, due for the most part to increased prices for oil and natural gas, which are basic requirements in the manufacture of synthetic rubber.

However, continued increases in gasoline prices and trends toward energy conservation have increased the demand for radial tires, which offer distinct fuel economy advantages.[28] The general decline in tire sales and the shift in demand toward radial tires has recently forced the closing of numerous bias tire plants.[8] However, despite the problems encountered due to the profitability of bias tire production, the demand for radial tires remains strong and it is generally recognized that new tire plants will be constructed for the production of radial tires.[25]

Tables 9-7 and 9-8 demonstrate the overall decline in both gross and net profits for several tire manufacturing firms. With regard to gross profits (Table 9-7), margins for the most recent year noted (1978) are the lowest

Table 9-7. PROFIT MARGINS[a] FOR TIRE MANUFACTURERS[b]

Year	Company								
	Armstrong	Cooper	Firestone	General	Goodrich	Goodyear	Mohawk	Michelin	Uniroyal
1978	8.9	6.0	8.7	9.6	9.2	10.7	7.5	N/A	6.2
1977	11.3	7.9	10.1	11.3	10.0	11.2	7.4	N/A	7.0
1976	10.1	10.0	10.1	11.1	8.2	9.5	10.2	N/A	6.5
1975	8.9	6.9	11.6	8.9	7.6	10.7	9.5	N/A	7.7
1974	8.9	1.6	12.3	8.9	9.8	11.3	6.0	-	8.7
1973	9.6	8.6	13.6	11.2	12.3	12.4	11.0	-	7.9
1972	12.8	9.8	13.9	12.8	13.0	13.6	11.5	-	8.4
1971	13.0	7.9	13.5	12.5	12.4	14.1	9.6	-	8.7
1970	11.5	6.3	12.0	10.6	11.6	12.8	8.2	-	7.4
1969	11.3	5.9	14.2	9.8	11.6	13.9	7.6	-	9.6

[a] Gross profit (i.e., before depreciation, interest, and federal taxes) as a percent of sales.

[b] Reference 5.

Table 9-8. NET PROFITS[a] FOR TIRE MANUFACTURERS[b]

	Company								
Year	Armstrong	Cooper	Firestone	General	Goodrich	Goodyear	Mohawk	Michelin	Uniroyal
1978	2.5	2.1	c	5.3	2.7	3.0	c	N/A	0.2
1977	4.1	3.1	2.5	5.5	2.7	3.1	2.1	N/A	1.4
1976	2.6	4.0	2.4	5.2	0.8	2.1	3.5	N/A	0.9
1975	1.6	2.7	3.6	3.6	1.3	3.0	2.9	3.2[d]	1.1
1974	1.7	c	4.2	4.5	2.8	3.0	1.0	-	2.1
1973	2.6	2.7	5.2	5.6	3.4	4.0	2.9	-	2.3
1972	3.5	3.2	5.0	6.0	3.4	4.7	3.4	-	2.6
1971	2.9	2.1	4.6	4.7	2.4	4.7	2.5	-	2.6
1970	2.1	1.2	4.0	3.9	1.0	4.0	1.6	-	1.6
1969	2.8	1.6	5.1	3.2	3.2	4.9	1.7	-	3.0

[a] Net Profit (i.e., after depreciation, interest, Federal, state and local taxes, and all costs) as a percent of sales.

[b] Reference 5.

[c] Deficit.

[d] Reference 31.

among the ten years listed, with the exception of 1976 during which the industry experienced major strikes. Industry analysts have predicted only small improvements in profit levels for 1980.[5]

It should be noted, however, that the profit summaries presented in Tables 9-7 and 9-8 relate to the profitability of tire manufacturing firms, and not necessarily the profitability of producing specific types of tires. Therefore the margins noted are for all tires including bias ply, bias belted and radials. It is generally accepted however, that the production of radial tires typically generates higher profit margins than the manufacture of bias tires.[5,29] Accordingly, the trend toward the manufacture and sale of radial tires is often cited as the bright spot in the future of those tire manufacturers who have established radial tire capacity.

Table 9-9 summarizes the return on equity for tire manufacturing firms, and in effect, demonstrates the declining profitability of ownership of such firms. The most recent data[30] suggests that the return on equity for tire and rubber companies was an industry composite of 7.8 percent, for the year ending December 31, 1979. As in the case of the profit summaries, return on equity data is presented at the firm level.

Profit and related information with regard to the Michelin Tire Corp. is largely unavailable as noted in Tables 9-7 through 9-9. The scarcity of such data is due mainly to the fact that the French-owned company, which started domestic production in 1974, is essentially privately held, with family members owning most of Michelin's stock.[31] However, several factors indicate that the profitability of this company is most likely greater than that of those firms noted. First, the company is a leading manufacturer of radial tires, having invented the radial in the early 1940's.[31] To the extent that higher profit margins are typically associated with radial tire production,[5,29] Michelin's margins should compare favorably with those producers who manufacture tires of other types of construction, as well as radials. Second, the company is currently undertaking a rapid expansion of its domestic productive capacity, a fact which indicates that its future earnings potential is viewed as favorable.

9.2.2.2 Market Structure and Industry Pricing. In its current state the market for tires can best be described as an oligopoly, characterized by the existence of two firms which act as "price leaders". In most cases price leaders exist either because their productive facilities are inherently more

Table 9-9. RETURN ON EQUITY[a] FOR TIRE MANUFACTURERS[b]

	Company								
Year	Armstrong	Cooper	Firestone	General	Goodrich	Goodyear	Mohawk	Michelin	Uniroyal
1979[c]	6.6	9.8	5.4	8.5	9.3	7.0	5.0	N/A	N/A
1978	7.7	11.0	d	12.7	8.0	11.1	d	N/A	0.2
1977	13.7	17.2	6.9	14.1	7.8	10.8	11.8	N/A	5.2
1976	8.2	25.6	6.2	14.2	1.9	6.6	19.0	N/A	2.7
1975	4.0	13.0	9.0	9.1	3.2	9.1	15.0	N/A	3.2
1974	4.0	N/A	11.0	12.3	7.3	9.2	4.9	-	7.9
1973	6.7	11.7	12.7	13.6	9.0	11.4	15.0	-	8.0
1972	9.2	13.3	11.2	12.7	7.8	12.7	14.4	-	8.2
1971	6.8	7.5	9.9	10.8	5.6	12.2	11.0	-	7.9
1970	5.6	3.7	8.6	9.2	2.1	9.9	6.3	-	4.1
1969	8.1	5.6	11.3	9.9	6.8	13.0	7.0	-	9.3

[a] Return on Equity = (Net Profit ÷ Total Equity) x 100.

[b] Reference 5, except 1979.

[c] Reference 30.

[d] Not meaningful.

efficient, and thus more profitable due to lower average costs, or because consumers display a strong preference for their products. The existence of price leader(s), is usually indicated if a disproportionate share of the total market is controlled by one or two producers.

The basic implication of price leadership is that the leader(s), due to the disparity in average costs among firms, or the preference of consumers for the products of the leader(s), have the ability to set prices with the intention of either increasing market shares or increasing total revenues. However, within limits, market shares of individual producers will be unaffected. This is so since, in the face of price reductions on the part of price leaders, the remaining industry participants will also lower prices, at the expense of their own profitability, and thus attempt to protect their individual market shares. On the other hand, when price leaders increase prices, the remaining firms will often raise prices in order to enhance the profitability of their own operations.

Goodyear and Firestone are generally recognized as the tire and rubber industry price leaders.[5] Evidence of their price leadership is ample as observed in the numerous instances of major industry representatives referring to current pricing practices as "cutthroat", and calling for major producers to "firm up prices" and institute "more rational pricing".[8,28] A more basic indicator of price leadership can be observed by the fact that together, Goodyear and Firestone share more than half of the total market for tires sold as original equipment.

The existence of price leadership will have direct implications regarding the full absorption or full pass through of NSPS control costs. More specifically, the price leaders, by raising the prices of tires produced at new plants, in order to pass through NSPS costs and thus preserve pre-NSPS levels of profit, will allow other manufacturers to do likewise. On the other hand, if current levels of price competition persist, the price leaders may choose to absorb the costs associated with NSPS, therefore reducing industrywide profits for new plants. In any event, if the price leaders choose to follow a full cost pricing policy, the maximum price increases which could result are small enough to ensure that market shares among industry participants will not be altered. Therefore, within the range of price change possible (see Table 9-13), the demand for tires is essentially price inelastic. The consequences of full cost pricing and full absorption are estimated in the following sections.

9.2.3 Economic Impact Methodology

9.2.3.1 Required Investment for New Tire Manufacturing Plants. Table 9-10 provides a summary of the total capital investment requirements for new radial tire manufacturing facilities. The estimates as presented provide a basis for determining both return on investment (ROI) and capital availability impacts as detailed in the following sections.

New plant investment requirements are distinguished by plant size, according to the model plant capacities and production rates discussed in Section 6.1.1. Investment totals are therefore presented for radial tire plants with capacities of 17,650, 35,300, and 58,825 TPD, and producing, with 85 percent capacity utilization, 15,000, 30,000, and 50,000 TPD. In addition, impacts upon a retrofit situation are assessed, with an assumed total retrofit of 44,118 TPD and output of 37,500 TPD for capacity utilization of 85 percent. Output of 37,500 TPD therefore requires six sidewall cementing lines (at 6,250 TPD each), five of both tread end and undertread cementing lines (at 7,500 TPD each), and three bead dipping lines (at 12,500 TPD each).

Total investment requirements are identified by three individual components: plant and equipment, land, and working capital. Plant and equipment investment data are based upon industry estimates[25] regarding the cost to construct and equip facilities of various sizes. Estimates of land costs have also been made,[25] however because of the extreme variability of such costs, due to size, location, and level of improvements needed, a constant estimate of such costs has been employed for all plants. Land costs have not been included in the retrofit situation.

Estimates of working capital, that is, the required investment in short-term assets such as cash, short-term securities, accounts receivable, and inventories, are based upon observations of working capital requirements, as reported in the annual reports of tire manufacturing companies. According to those reports the ratio of working capital to sales typically approaches 20 percent. Thus for purpose of the following analysis, working capital requirements are estimated as 20 percent of annual plant revenues. The estimation of annual revenues for each model plant is described in the following section.

9.2.3.2 Annual Revenues of New Tire Manufacturing Plants. Annual revenues, expected to be generated through the manufacture and sale of radial tires, have been estimated for each model plant. The estimation of annual revenues allows the determination of maximum tire price increases, as well

Table 9-10. INVESTMENT REQUIREMENTS FOR NEW RADIAL TIRE MANUFACTURING PLANTS ($000 1979)

Investment Component		Model Plant Size			Retrofit
	Capacity (TPD)	17,650	35,300	58,825	44,118
	Output (TPD)	15,000	30,000	50,000	37,500
Plant and Equipment		149,800	243,300	347,800	284,300
Land		8,000	8,000	8,000	-
Working Capital		28,200	56,500	94,200	70,600
Total Investment		186,000	307,800	450,000	354,900

Table 9-11. ANNUAL REVENUES FOR NEW RADIAL TIRE MANUFACTURING PLANTS ($000 1979)

	Plant Output in Tires/Day			
	15,000	30,000	50,000	37,500
Days/Year	269	269	269	269
$/Tire	$ 35.00	$ 35.00	$ 35.00	$ 35.00
Annual Revenue	$141,200	$282,500	$470,800	$353,100

as maximum profit reduction, under the full pass through and full absorption assumptions employed below.

The derivation of the annual revenues expected of each model plant is summarized in Table 9-11. The levels of daily production as well as days of operation per year are explained in Section 6.1, while the average wholesale value of radial tires is based upon estimates made available by the Department of Commerce.[26]

9.2.3.3 Return on Investment (ROI) for New Tire Manufacturing Plants. In order to estimate the extent to which the profitability of new tire plants, as well as the prices of tires produced, could be affected by the full absorption or pass through of NSPS control costs, it is first necessary to identify a reasonable ROI that can be expected of new tire production facilities in the absence of NSPS. However, the competitive nature of the industry and the proprietary status of profit related data, have eliminated the possibility of identification of a "target" ROI, by industry representatives. However, publicly available data, in the form of recent rates of return on equity for the tire and rubber industry, make possible the estimation of the minimum acceptable ROI for new plant construction.

Since ROI is the expression of net profits (i.e., profit after depreciation, interest payments, and taxes) as a percent of total investment, a measure of the overall profitability of a new investment can be obtained by:

$$\text{Return on Investment} = \frac{\text{net profit}}{\text{total investment}} \times 100 \qquad (1)$$

However, a more appropriate measure of profitability, from the owners' (shareholders) point-of-view is the return on equity, which recognizes that only a portion of the total investment has been financed by the owners (shareholders), with the remainder financed through debt upon which interest payments are made. The return on equity therefore, recognizes the impact of debt leverage upon earnings. Therefore since net profits are determined after the payment of interest:

$$\text{Return on Equity} = \frac{\text{net profit}}{\text{total equity}} \times 100 \qquad (2)$$

or:

$$\text{Return on Equity} = \frac{\text{return on investment}}{\text{\% of total investment financed by equity}} \qquad (3)$$

The use of current rates of return on equity to estimate minimum acceptable new plant profitability (ROI), is based on the assumption that the managers of tire manufacturing firms will not approve the construction of new tire plants which, due to low projected ROI's, could lower prevailing rates of return on equity, and thus dilute the earning potential of the firm. Therefore, only those new plants which can promise ROI high enough to insure that the return on equity (as estimated by equation (3) above), will at least not decrease, will be considered as potential investments.

The most recent available data suggests that for 1979 the return on equity for major tire and rubber manufacturers was an industry composite of 7.8 percent.[30] Furthermore, the percentage of debt to debt plus equity has been observed as an industry average of 36 percent.[5] This data indicates that as an absolute minimum, any new plant must show an ROI (i.e., return on total investment after taxes, depreciation, and interest) of at least 5 percent since, according to equation (3):

$$7.8\% = \frac{5.0\%}{(1 - .36)} \tag{3a}$$

Therefore, for purpose of this analysis, a 5 percent baseline ROI is assumed for new tire plants since the investment in new plants which would return less could result in the reduction of current levels of profitability of ownership (i.e., return on equity).

This estimate is considered to be conservative since it is based upon industry-wide rates of return on equity and consequently, reflects the profitability of producing all types of tires including bias-belted, bias-ply, and radial tires. However, since new plant construction will be undertaken in order to satisfy the demand for radial tires, and the manufacture of radials is generally recognized to yield higher profit margins,[5,29] it is most probable that an estimated return of 5 percent understates the actual ROI for new plants. In addition, to the extent that the declining book value of total assets is not offset by increasing annual maintenance costs, the ROI for an individual new plant should increase from year to year.

The 5 percent ROI for new plants, as estimated above, in conjunction with the investment and revenue estimates summarized in Tables 9-10 and 9-11, can be employed in the determination of the absolute levels of costs, earnings before federal taxes, federal taxes, and net profits for each model plant. These estimates are summarized in Table 9-12 and are used in the approximation of the profitability, price, and capital availability impacts as detailed in the following sections. For the retrofit situation profitability impacts have been assessed by treating the new lines as an individual profit center with ROI identical to that for a new plant.

9.2.3.4 Estimation of Price Impacts Under Full Cost Pricing. In the event the actions of the price leaders allow the pass through of control costs, the methodology detailed below has been employed to estimate the increases in tire prices required to ensure that manufacturers will maintain baseline levels of ROI. The estimation of price impacts is based upon the assumption that manufacturers will price their products so that all costs are covered and a minimum ROI is achieved. In this manner baseline prices are set by:

$$P = \frac{TC + (ROI \times TI)/(1 - t)}{Q} \qquad (4)$$

where;

P = Price Per Unit ($/tire)
TC = Total Costs ($)
TI = Total Investment ($)
Q = Unit Production Per Year (tires/year)
t = Federal Tax Rate (.46)
ROI = Return on Total Investment (expressed as a decimal).

When data for any of the model plants summarized in Table 9-12 is substituted into this equation, an average wholesale price of $35 per tire is observed. This result is based upon an ROI of 5 percent and 269 operating days each year.

As a consequence of NSPS controls, new plants will incur increased costs in the form of capital changes and operating and maintenance costs. In addition, a larger asset base will be required. Therefore, maximum price increases can be traced to both cost increases as well as to a return for the additional capital investment in controls. Consequently, post-NSPS prices may be estimated through the following modification of equation (4):

Table 9-12. BASELINE REVENUE, COST, TAX AND PROFIT SUMMARY FOR MODEL TIRE MANUFACTURING PLANTS
($000 1979)

	Model Plant Size			Retrofit
Capacity (TPD)	17,650	35,300	58,825	44,118
Output (TPD)	15,000	30,000	50,000	37,500
Total Investment[a]	186,000	307,800	450,000	354,900
Annual Revenue[b]	141,200	282,500	470,800	353,100
Total Costs[c]	123,978	254,000	429,133	320,239
Earnings Before Federal Tax[d]	17,222	28,500	41,667	32,861
Federal Tax[e]	7,922	13,110	19,167	15,116
Net Profits[f]	9,300	15,390	22,500	17,745

[a] See Table 9-10.

[b] See Table 9-11.

[c] Total Costs = Annual Revenue - Earnings Before Federal Tax (Total Costs includes all operating costs, general and administrative expenses, local and state taxes, depreciation, and interest).

[d] Earnings Before Federal Tax = Net Profit/(1-.46) (assumes Federal tax rate of 46%).

[e] Federal Tax = Earnings Before Federal Tax x .46.

[f] Net Profits = Total Investment x .05.

$$P' = \frac{(TC + ACC) + [ROI \times (TI + CC)]/(1 - t)}{Q} \qquad (5)$$

where;

ACC = Annualized Control Costs
CC = Capital Control Costs.

The annualized control costs (ACC) include capital charges for the annual repayment of principal and interest on a uniform basis, to finance a loan for the control investment. To be consistent with the method in which the ROI reported in this analysis was derived, capital changes as mentioned above are used as a surrogate for the normal depreciation and interest charges that a typical firm may deduct as allowable expenses for tax purposes. Since firms with 100 percent financing would probably benefit through the use of accelerated depreciation, it is believed that the procedure used in this analysis would generate conservative results in the first few years of a project, such as the radial tire plants summarized in Table 9-12.

The results of the comparison of baseline and post-NSPS prices, under each regulatory alternative are summarized in Section 9.2.4.1. In that section the implications of the full pass through of control costs are expressed in terms of the percentage increase in average wholesale tire prices where:

$$\text{Percent Change} = \frac{\text{post-NSPS price - baseline price}}{\text{baseline price}} \times 100 \qquad (6)$$

9.2.3.5 Estimation of Rate of Return on Investment Impacts Under Full Cost Absorption. If due to market conditions, the cost of NSPS controls cannot be passed to consumers in the form of increased tire prices, the profitability of new plants will decline. In order to judge the extent of profitability impacts, the ROI before and after NSPS controls, have been compared for each model plant, according to the method detailed below.

The baseline ROI for each model plant is essentially:

$$ROI = \frac{(1 - t)(AR - TC)}{TI} \qquad (7)$$

where:

t = Federal Tax Rate (.46)
AR = Annual Revenue ($)
TC = Total Costs ($)
TI = Total Investment ($)
ROI = Return on Total Investment (expressed as decimal).

This equation is simply a restatement of equation (1) noted above, and if used in conjunction with the investment, cost, and profit data of Table 9-12, an ROI of 5 percent for each model plant is observed.

The full absorption of control costs implies that the annualized costs of control will increase total annual costs, and thus decrease earnings before federal tax for new plants. In addition the need to install control equipment entails capital control costs and will therefore increase the total investment required for new plant construction. Considering these additional costs, the post-control ROI for each model plant may be estimated through the following modification of equation (7):

$$ROI' = \frac{(1 - t)(AR - TC - ACC)}{TI + CC} \qquad (8)$$

where:

ACC = Annualized Control Costs
CC = Capital Control Costs.

It should be noted that the approach described above assumes that both the capacity utilization rates and marginal tax rates will remain constant before and after NSPS. The results of the calculation of post-NSPS ROI for each model plant are summarized in Section 9.2.4.2.

9.2.4 Economic Impacts

9.2.4.1 Price Impacts. Section 9.2.3.4 has detailed the methodology used to estimate the level of price increases required if the full costs of NSPS control are passed to consumers in the form of increased tire prices.

Percentage price increases are summarized in Table 9-13 where individual percentage price increases are distinguished according to model plant size and control system employed.

Table 9-13. PERCENT CHANGES IN PRICE UNDER FULL COST PRICING

Model Plant (TPD)	Control System		
	Carbon Adsorber	Thermal Afterburner	Catalytic Afterburner
15,000	.14	.44	.42
30,000	.13	.36	.35
50,000	.11	.34	.32
37,500 (retrofit)	.14	.41	.42

Table 9-13 indicates that maximum average tire percentage price increases are generally low. For example, the table shows that in the worst case, that is, the most costly control system for the small plant, would increase prices by .44 percent. Based on an average wholesale radial tire price of $35, the full pass through of control costs would add 15 cents to the wholesale price.

It should be noted, however that the control of VOC emissions through carbon adsorption is significantly less costly under all circumstances. For example, the use of carbon adsorption in the worst case situation noted above would increase prices by .14 percent, or 5 cents for the same $35 tire.

It should also be noted that the costs used to determine both price and profitability impacts are those related to the control of sidewall, undertread, bead, and tread end cementing facilities.

The previously discussed price-cutting activities of industry price leaders, may result in conditions where NSPS costs must be fully absorbed by all firms operating new plants. Under these circumstances the level of profit reduction which may result from the full absorption of NSPS control costs are discussed below.

9.2.4.2 Rate of Return on Investment Impacts. If, for reasons detailed previously, the full costs of NSPS controls are not passed to consumers in the form of price increases, the profitability of new tire manufacturing facilities will be affected. Estimates of the extent to which profitability may decline, have been made according to the procedure detailed in Section 9.2.3.5. Accordingly, the results summarized in Table 9-14 identify the post-NSPS ROI resulting from the full absorption of NSPS control costs.

As might be expected, the severity of profitability impacts follow the same patterns observed with regard to potential price increases. More specifically, the use of carbon adsorption for VOC emission reduction, entails significantly lower impacts in terms of reductions in ROI. In general, the retrofit situation entails slightly larger levels of net profit reduction.

ROI reductions of the magnitude noted above, cannot be considered impediments to new plant construction or retrofit. This is especially true in light of two important factors. First, it may be recalled that the 5 percent baseline ROI was estimated in such a way that this base ROI level must be considered conservative (see Section 9.2.3.3). To the extent the actual ROI for

Table 9-14. RETURN ON INVESTMENT (ROI) UNDER FULL COST ABSORPTION
(Baseline ROI = 5.00 percent)

Model Plant (TPD)	Control System		
	Carbon Adsorber	Thermal Afterburner	Catalytic Afterburner
15,000	4.94	4.81	4.82
30,000	4.94	4.83	4.84
50,000	4.94	4.81	4.83
37,500 (retrofit)	4.93	4.79	4.78

new plants is higher, the ROI changes may be slightly overstated. Second, the existence of price leadership in the industry suggests that profitability impacts could be altogether avoided if price leaders choose to follow a full cost pricing policy.

9.2.4.3 Capital Availability Impacts. Since each of the regulatory alternatives requires capital expenditures for VOC control equipment, the need for such equipment requires that potential investors in new tire manufacturing facilities must obtain additional capital financing above that which would be required in the absence of regulation. However, capital availability problems will not result from the imposition of NSPS for new or retrofitted tire manufacturing plants. This is so because in no case, do the capital control costs represent more than 1 percent of the total investment requirements summarized in Table 9-10.

9.3 SOCIOECONOMIC AND INFLATIONARY IMPACTS

9.3.1 Fifth-Year Annualized Costs

Fifth-year annualized costs have been estimated in order to determine if this NSPS qualifies a major regulation under the $100 million criteria specified by E.O. 12291. Since higher costs are generally associated with the retrofit of existing lines, fifth-year annualized costs have been estimated by adding the annualized costs of NSPS for those retrofitted lines expected to be affected by this standard.

As noted in Section 9.1.3, the growth in demand for radial tires is projected to be such that 73 retrofitted lines may be required by 1985. Specific requirements are: 23 sidewall cementing lines, 19 tread end cementing lines, 19 undertread cementing lines, and 12 bead dipping lines. According to these projections and the annualized costs presented in Table 8-11, the use of the most expensive control technology would result in fifth-year annualized costs of $4.8 million. In reality, the use of the most cost-efficient control systems will reduce this sum to $1.2 million.

9.3.2 Inflationary Impacts

For 1978, the sales of 6 major tire producers amounted to less than 1 percent of that year's GNP.[4] This fact in conjunction with the low (.4 percent) maximum price increases (Table 9-13), ensures that the imposition of the regulatory alternative will cause virtually no increase in the rate of inflation.

9.3.3 Employment Impacts

As noted in Section 9.2 the cost of NSPS could have very minimal impacts upon new plant profitability. Under these conditions the decision to construct new tire plants will be unaffected by NSPS controls. For this reason the standard will have no impact upon employment trends in the industry.

9.3.4 Small Business Impacts

The Regulatory Flexibility Act of 1980 requires the identification of possible adverse impacts of Federal regulations upon small entities including small businesses. Small businesses are defined as business concerns that are not dominant in their respective fields. Concerning tire manufacturing, the Small Business Administration has identified small businesses as those that employ fewer than 1,000 persons. This employment level has been defined by the Small Business Administration for purpose of pollution control guarantee assistance under Public Law 94-305, and is noted in Federal Register 36052, August 15, 1978.

There are currently three tire manufacturers that have fewer than 1,000 employees, namely Denman of Warren, Ohio; McCreary of Indiana, Pennsylvania; and Ironside of Louisville, Kentucky.[32] Since it is most likely that any new plant would employ at least 1,000 persons,[25] the companies noted above would probably not become subject to NSPS through new plant construction. If the small companies are affected through modifications and/or reconstructions of existing facilities, economic impacts will be very small as estimated through the analysis of retrofitted plants.

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APPENDIX A

EVOLUTION OF THE PROPOSED STANDARDS

APPENDIX A - EVOLUTION OF THE PROPOSED STANDARDS

A.1 INTRODUCTION

In December 1974, the Industrial Environmental Research Laboratory of the U.S. Environmental Protection Agency initiated a Source Assessment/State-of-the-Art Study of rubber processing. The study was authorized under Section 313 of the Clean Air Act, which charges the Administrator of EPA with the responsibility of establishing Federal standards of performance for new stationary sources which may significantly contribute to air pollution. Concurrently, a screening study of nine segments of the rubber industry was initiated for the purpose of identification and control of hydrocarbon emissions. As a result of the screening study, the tire and inner tube industry segment proved to have the highest potential for reduction of hydrocarbon emissions through implementation of NSPS. The EPA Priority List (40 CFR 60.16, 44 FR 49222, August 21, 1979) shows tire manufacturing to be a division under the source category of synthetic rubber, which is ranked twentieth in priority. The method used to rank the source categories was based on emissions, public health/welfare, and source mobility. These criteria were set forth by Congress in the 1977 Clean Air Act Amendements.

Standards development for the rubber tire industry involved collection of solvent use data and performance of emission measurement tests to quantify and identify source emissions. Plant visits were scheduled to obtain information on process details and emission control equipment, while literature surveys were conducted to determine plant operating parameters and the extent of use of emission reduction techniques. EPA scheduled meetings with Rubber Manufacturing Association (RMA) representatives to discuss relevant issues which pertained to the development of the standards. The significant events relating to the effort of developing the new source performance standards (NSPS) for the rubber tire industry are discussed in the chronology below.

A.2 CHRONOLOGY

The following chronology lists important events which have occurred in the development of background information for the rubber tire manufacturing NSPS.

Date	Activity
August 1975	Preliminary report prepared by the Monsanto Research Corporation entitled Source Assessment, Rubber Processing, State-of-the-Art.
May 1976	Screening study of nine segments of the rubber industry initiated.
July 7, 1976	Meeting with Environmental Committee representatives of RMA and EPA to discuss the screening study.
July 20, 1976	Meeting with Environmental Committee of RMA and Monsanto Research Corporation representatives to schedule plant visits to nine segments of the industry.
August 2, 1976	RMA's position regarding the development of guidelines document for the rubber industry is confirmed.
December 20, 1976	Information requests sent to rubber industry regarding data for screening study.
December 21, 1976	Visit to Armstrong Rubber Company, West Haven, Connecticut plant - rubber tire manufacturing.
December 22, 1976	Visit to Uniroyal, Chicopee Falls, Massachusetts plant - rubber tire manufacturing.
January 13, 1977	Plant visit to Uniroyal Incorporated, Red Oaks, Iowa plant - rubber hose manufacturing.
February 8, 1977	Visit to Gates Rubber Company, Denver, Colorado plant - rubber hose and belt manufacturing.
November 23, 1977	Second draft of the screening study entitled "Identification and Control of Hydrocarbon Emissions from Rubber Processing Operations" finalized. Decision made to pursue development of guidelines document and NSPS for rubber tires.
January 20, 1978	Information requests for development of NSPS sent to eight rubber tire manufacturers.

Date	Activity
May 1978	NSPS contract awarded to Monsanto Research Corporation.
May 9, 1978	Meeting with RMA Environmental Committee and EPA to discuss research and development activities for capture systems in the curing areas.
September 13, 1978	Meeting with RMA Environmental Committee and EPA to initiate work on the design of a capture system to control emissions from tire curing operations.
October 6, 1978	Follow-up information requests sent to five rubber tire manufacturers.
December 1978	Final draft of guidelines document entitled "Control of Volatile Organic Emissions from Manufacture of Pneumatic Rubber Tires (CTG)" released.
January 22-26, 1979	Emission tests and measurements performed at Armstrong Rubber Company, West Haven, Connecticut.
April 1979	NSPS contract awarded to Pacific Environmental Services, Incorporated.
June 6, 1979	Visit to Firestone Tire and Rubber Company, Wilson, North Carolina plant - rubber tire manufacturing.
July 19, 1979	Model plant parameters for rubber tire NSPS proposed.
July 27, 1979	Visit to Armstrong Rubber Company, West Haven, Connecticut plant - rubber tire manufacturing.
August 21, 1979	EPA Priority List 40 CFR 60.16, 44 FR 49222, August 21, 1979, Synthetic Rubber ranked twentieth in priority.
August 27 - September 4, 1979	Emission measurements performed at Armstrong Rubber Company, West Haven, Connecticut.
November 5-9, 1979	Emission measurements performed at Kelly-Springfield, Fayetteville, North Carolina.

Date	Activity
November 7, 1979	Visit to Kelly-Springfield Tire Company, Fayetteville, North Carolina plant - rubber tire manufacturing.
December 31, 1979 - January 4, 1980	Emission measurements performed at Michelin Tire Company, Greenville, South Carolina plant.
January 24, 1980	Follow-on information requests sent to eight rubber tire manufacturers.
June, 1980	Preliminary tests to determine effects of absorption on evaporation of VOCs from rubber components.
June 2, 1980	EPA/CPB and EPA/SDB concurrence on regulatory approach.
June 27, 1980	Draft BID, Chapters 2-8 and Appendices B-D, distributed to EPA Working Group and to industry members.
July 31, 1980	Meeting between rubber tire manufacturing industry representatives and EPA staff to discuss draft BID.
October 31, 1980	Draft BID, Chapters 2-9 and Appendices A-D, distributed to EPA National Air Pollution Control Techniques Advisory Committee (NAPCTAC).
November 26, 1980	Draft BID, Chapters 2-9 and Appendices A-D, distributed to EPA Steering Committee.
December 1980	EPA Steering Committee review.
December 2, 1980	NAPCTAC meeting, all comments were recorded.
January 14, 1981	NAPCTAC meeting minutes released for public review.

APPENDIX B

INDEX TO ENVIRONMENTAL CONSIDERATIONS

This appendix consists of a reference system which is cross indexed with the October 21, 1974, Federal Register (39 FR 37419) containing EPA guidelines for the preparation of Environmental Impact Statements. This index can be used to identify sections of the document which contain data and information germane to any portion of the Federal Register guidelines.

APPENDIX B

INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS

Agency Guidelines for Preparing Regulatory Action Environmental Impact Statements (39 FR 37419)	Location Within the Background Information Document (BID)
1. Background and Description of Emissions and Emission Controls	
Statutory Basis for Development of New Source Performance Standards (NSPS).	The statutory basis for NSPS is given in Chapter 2.
Activities Affected	Descriptions of the activities which emit pollutants to be affected are given in Chapter 3, Section 3.1.
Process Affected	The activities to be affected are listed in Chapter 4, Section 4.0.
Availability of Control Technology	Information on the availability of control technology is given in Chapter 4.
Existing Regulations at State or Local Level	A discussion of existing regulations or the industry to be affected by the standards is included in Chapter 3, Section 3.3.
2. Regulatory Alternatives	
Regulatory Alternative I	
Environmental Impacts	The environmental impacts associated with Regulatory Alternative I emission control systems are considered in Chapter 7.
Costs	The cost impact of Regulatory Alternative I emission control systems is considered in Chapter 8, Section 8.2.

(Continued)

INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS (Continued)

Agency Guidelines for Preparing Regulatory Action Environmental Impact Statements (39 FR 37419)	Location Within the Background Information Document (BID)
Health and Welfare Impact	The impact of Regulatory Alternative I emission control systems on health and welfare is considered in Chapter 6.
Regulatory Alternative II	
Environmental Impacts	The environmental impacts associated with Regulatory Alternative II emission control systems are considered in Chapter 7.
Costs	The cost impact of Regulatory Alternative II emission control systems is considered in Chapter 8, Section 8.2.
Health and Welfare Impact	The impact of Regulatory Alternative II emission control systems on health and welfare is considered in Chapter 6.
Regulatory Alternative III	
Environmental Impacts	The environmental impacts associated with Regulatory Alternative III emission control systems are considered in Chapter 7.
Costs	The cost impact of Regulatory Alternative III emission control systems is considered in Chapter 8, Section 8.2.
Health and Welfare Impact	The impact of Regulatory Alternative III emission control systems on health and welfare is considered in Chapter 6.
3. Environmental Impact of Regulatory Alternatives	
Air Pollution	The air pollution impact of the regulatory alternatives is considered in Chapter 6, Section 6.1.

(Continued)

INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS (Concluded)

Agency Guidelines for Preparing Regulatory Action Environmental Impact Statements (39 FR 37419)	Location Within the Background Information Document (BID)
Water Pollution	The impact of the regulatory alternatives on water pollution is considered in Chapter 6, Section 6.1.
Solid Waste Disposal	The impact of the regulatory alternatives on solid waste disposal is considered in Chapter 6, Section 6.3.
Energy	The impact of the reguatory alternatives on energy use is considered in Chapter 6, Section 6.4.
Costs	The impact of the regulatory alternatives on costs is considered in Chapter 7, Section 7.2.

APPENDIX C - EMISSION DATA

C.1 SUMMARY OF ACTIVITY

Methods and data used to calculate emissions from rubber tire manufacturing plants are presented in this appendix. Emission test methods and data from tests at two rubber tire manufacturing plants are also presented. Information used to calculate industry emission rates and uncontrolled emission factors was obtained from industry responses to two U.S. Environment Protection Agency inquiries conducted under authority of Section 114 of the Clean Air Act. Industry Survey I was a request for information which reported quantities of VOCs used and operating parameters for all solvent consuming operations within a tire plant. Survey I information reported data for the most recent year available: some plants responded with data for 1976 while others reported 1977 information. Industry Survey II concentrated on acquisition of VOC consumption data and process description data for selected solvent-consuming plant processes. Industry Survey II data pertained to tire manufacturing for the three year period, 1977-1979.

Two stages of tests were performed at two rubber tire manufacturing plants in order to assist in the development of emissions data for the industry. The objectives of the first stage of tests performed at one plant were: (1) to determine VOC removal efficiency of the carbon adsorber used at the undertread cementing operation, (2) to determine cement usage at the undertread operation, and (3) to compare two test methods for VOC measurement. The second stage of tests was conducted at two plants; one was the same plant at which the first stage of tests was performed. Test objectives at both plants were: (1) to determine evaporation rates for VOCs applied to rubber components at tread end cementing and bead cementing operations, (2) to determine cement usage at tread end cementing and bead cementing operations, (3) to determine the mass of VOC to mass of cement used at tread end cementing operations, and (4) to compare any variations in VOC emissions between different tread end cement and bead cement application methods.

C.2 PRESENTATION OF SOLVENT CONSUMPTION DATA AND OPERATING PARAMETERS

Section 114 requests for information were necessary on two occassions to obtain solvent consumption data for tire manufacturing plants.

Information requested in Industry Survey I was used for: (1) determining which tire producing processes would be considered for emission control and (2) developing model plant parameters. Information obtained from Industry Survey II provided for: (1) expansion of the data base for specific solvent-consuming processes to a three year period, and (2) detailed process descriptions of cement or spray application methods.

Tables C-1 through C-18 present solvent consumption data and/or properties of the exit gas for all tire manufacturing plants that responded to the surveys.

Table C-1 lists the total annual consumption of volatile organic compounds at 42 tire manufacturing plants, representing eight companies that responded to Industry Survey I. Tables C-2 through C-18 list annual solvent consumption data as reported in Industry Surveys I and II. Out of a total of thirty-six plants, representating seven tire companies reporting Industry Survey II information, only thirty-two plants are listed in the tables, as four plants that exclusively produce tires other than those considered in development of the standard were excluded.

In order to arrive at solvent consumption values presented in the following tables, densities of specific organic compounds were used to convert solvent consumption, reported in gallons, to mass. Assumptions used in the conversions include:

- the density of naphtha and any "rubber solvents" of unspecified composition is 5.49 lb/gal (666 gm/l);
- the density of gasoline is equal to that of octane, 5.87 lb/gal (703 gm/l);

The density of heterogeneous solvents were calculated by summing the weighted densities of individual VOC constituents. Solvent consumption data is used to generate emission factors. These factors represent 100 percent of solvent usage reported in the Section 114 responses, except in the case of water-based green tire sprays. In the case of water-based green tire sprays the organic solvent content, expressed as weight percent, is incorporated into the calculation in order to report the mass of VOCs used.

Table C-1. TOTAL SOLVENT CONSUMPTION DATA FROM TIRE MANUFACTURING PLANTS IN 1977

(Industry Survey I)

Plant Code	VOC CONSUMPTION		Plant Code	VOC CONSUMPTION	
	Mg	Tons		Mg	Tons
A	1,042	1,149	EE	963	1,062
B	33	36	FF	209	230
C	567	625	GG	1,564	1,724
D	962	1,061	HH	1,342	1,480
E	774	853	JJ	1,334	1,471
I	852	939	LL	4,387	4,837
K	1,296	1,429	NN	624	688
L	249	275	OO	856	944
M	2,578	2,842	PP	385	424
O	1,719	1,895	QQ	1,213	1,337
P	1,341	1,478	RR	476	525
Q	1,371	1,512	SS	673	742
R	1,218	1,343	TT	1,334	1,471
T	712	785	UU	1,032	1,138
V	1,705	1,880	WW	1,719	1,895
W	266	293	XX	1,287	1,419
X	1,025	1,130	YY	1,058	1,166
Y	1,188	1,310	ZZ	202	223
Z	1,646	1,815	AAA	605	667
BB	56	62	BBB	743	819
DD	790	871	CCC	223	246

Table C-2. OPERATING PARAMETERS FOR UNDERTREAD CEMENTING
(Industry Survey I)

Plant Code	Number of undertread cementing lines	Exit gas properties: Flow rate, m^3/s per line: Average	Exit gas properties: Flow rate, m^3/s per line: Range	Exit gas properties: Temperature, °C	Exit gas properties: Gauge Pressure Pa
A	-[a]	-[b]	-[a]	-[a]	-[a]
B	-[a]	-[b]	-[a]	-[a]	-[a]
C	2	1.5	0.6-2.4	-[c]	530-800
D	3	2.0	-[d]	-[c]	0
E	4	2.8	1.2-4.4	-[c]	0
I	2	2.6	-[d]	-[c]	0
K	2	3.8	-[d]	-[c]	0
L	-[a]	-[b]	-[a]	-[c]	0
M	-[a]	-[b]	-[a]	-[a]	-[a]
O	-[a]	-[b]	-[a]	-[a]	-[a]
P	3	1.9	-[d]	-[c]	530
Q	-[a]	-[b]	-[a]	-[a]	-[a]
R	3	2.5	-[d]	-[c]	0
T	8	3.6	1.9-3.8	-[c]	130
V	8	3.8	-[d]	-[c]	-[a]
W	2	3.3	3.2-3.5	-[c]	0
X	13	3.3	-[d]	-[c]	0
Y	1	5.7	-[e]	-[c]	0
Z	-[a]	-[b]	-[a]	-[a]	-[a]
BB	-[a]	-[b]	-[a]	-[a]	-[a]
DD	-[a]	-[b]	-[a]	-[a]	-[a]
EE	-[a]	-[b]	-[a]	-[a]	-[a]
FF	1	2.6	-[e]	-[c]	530
GG	4	2.8	-[d]	-[c]	-[a]
HH	-[a]	-[b]	-[a]	-[a]	-[a]
JJ	2	2.4	-[d]	-[c]	800
LL	5	1.4	-[d]	-[c]	-[a]
NN	2	1.5	-[d]	-[c]	530
OO	-[a]	-[b]	-[a]	-[a]	-[a]
PP	4	1.0	-[d]	25-30	0
QQ	-[a]	-[b]	-[a]	-[c]	0
RR	2	2.0	1.4-2.6	-[c]	270-2,500
SS	2	3.2	-[d]	27	-[a]
TT	-[a]	-[b]	-[a]	-[a]	-[a]
UU	4	1.8	-[a]	-[c]	0
WW	3	3.8	-[d]	21	0
XX	-[a]	-[b]	-[a]	-[a]	-[a]
YY	3	4.4	-[d]	-[c]	0
ZZ	-[a]	-[b]	-[a]	-[c]	0
AAA	-[a]	-[b]	-[a]	-[c]	0
BBB	-[a]	-[b]	-[a]	-[a]	-[a]
CCC	-[a]	-[b]	-[a]	-[a]	-[a]

[a] Not available.
[b] Not calculated
[c] Ambient
[d] All units have same exit gas flow rate.
[e] Only one value reported.

Table C-3. SOLVENT CONSUMPTION DATA FOR UNDERTREAD CEMENTING

(Industry Survey I)

Plant Code	VOC CONSUMPTION Mg	VOC CONSUMPTION Tons
A	[b]	[b]
B	[b]	[b]
C	203	224
D	296	326
E	494	545
I	189	208
K	305	336
L	15	17
M	[b]	[b]
O	[b]	[b]
P	586	648
Q	197	217
R	361	398
T	641	709
V	[b]	[b]
W	230	253
X	472	520
Y	511	563
Z	[b]	[b]
BB	26	
DD	[b]	29
EE	248	273
FF	177	195
GG	968	1,067
HH	[b]	[b]
JJ	416	459
LL	236	260
NN	195	215
OO	[b]	[b]
PP	84	93
QQ	[b]	[b]
RR	301	332
SS	113	125
TT	479	528
UU	459	506
WW	804	886
XX	470	518
YY	758	836
ZZ	[b]	[b]
AAA	94	104
BBB	297	327
CCC	31	34

[a] Not available.

[b] Not calculated.

[c] Ambient.

[d] All units have same exit gas flow rate.

[e] Only one value reported.

Table C-4. SOLVENT CONSUMPTION DATA FOR UNDERTREAD CEMENTING
(Industry Survey II)

Plant Code	VOC CONSUMPTION 1977		VOC CONSUMPTION 1978		VOC CONSUMPTION 1979	
	Mg	Tons	Mg	Tons	Mg	Tons
A	[a]	[a]	[a]	[a]	[a]	[a]
B	[a]	[a]	17.0	15.8	90.5	99.7
C	464.9	512.5	409.2	451.0	245.3	270.4
E	482.3	531.6	418.4	461.2	436.6	481.3
F	229.7	253.2	231.6	255.3	224.1	247.0
G	591.6	652.1	669.7	738.2	550.3	606.6
H	54.0	(59.6	48.8	53.8	41.3	45.6
I	440.2	485.2[b]	468.6	516.5[b]	437.7	482.5[b]
J	[a]	[a]	[a]	[a]	[a]	[a]
K	390.4	430.3[b]	999.0	1101.2[b]	827.5	912.2[b]
L	700.6	772.2[b]	650.1	716.6[b]	651.0	717.6[b]
N	191.0	210.5	256.5	282.7	212.6	234.4
P	352.0	388.0	351.5	387.5	289.4	319.0
R	501.7	553.0	277.3	305.7	277.2	305.5
S	37.2	(41.0	29.8	(32.8	28.8	31.7
T	505.3	556.9[b]	505.3	556.8[b]	546.9	602.8[b]
U	373.0	411.2	372.7	410.9	358.6	395.3
V	846.1	932.6	279.8	308.4	163.7	180.4
W	476.2	524.9[b]	560.5	617.8[b]	556.8	613.7[b]
X	802.4	884.4[b]	847.8	934.5[b]	747.0	823.4[b]
Z	241.0	265.6	683.6	753.5	730.0	804.6
AA	53.9	59.4	66.8	(73.6	53.4	58.9
BB	490.9	541.1[b]	290.9	320.7[b]	266.7	294.0[b]
CC	[a]	[a]	845.1	931.3	[a]	[a]
DD	258.2	284.6	241.9	266.7	270.7	298.4
EE	858.1	945.9	388.9	428.7	283.8	312.8
FF	422.5	465.7	410.6	452.6	353.9	390.1
GG	[a]	[a]	[a]	[a]	[a]	[a]
HH	180.3	198.7	[a]	[a]	[a]	[a]
II	274.7	302.8	256.7	282.9	193.1	212.9
JJ	1036.5	1142.6	904.6	997.2	471.4	519.6

[a] Blank indicates that annual mass of solvent consumption could not be calculated.

[b] Sidewall and undertread cementing were reported together in the same number.

Table C-5. SOLVENT CONSUMPTION DATA FOR TREAD END CEMENTING[a]

(Industry Survey I)

Plant Code	VOC CONSUMPTION		Plant Code	VOC CONSUMPTION	
	Mg	Tons		Mg	Tons
A	7	8	EE	31	34
B	a	a	FF	21	23
C	22	24	GG	28	31
D	75	83	HH	a	a
E	12	13	JJ	135	149
I	30	33	LL	22	24
K	40	44	NN	57	63
L	a	a	OO	36	40
M	a	a	PP	a	a
O	a	a	QQ	a	a
P	120	132	RR	33	36
Q	158	174	SS	210	232
R	18	20	TT	89	98
T	a	a	UU	167	184
V	10	11	WW	18	20
W	18	20	XX	46	51
X	29	32	YY	22	24
Y	52	57	ZZ	a	a
Z	a	a	AAA	4	4
BB	a	a	BBB	31	34
DD	a	a	CCC	9	10

[a] Blank indicates that annual mass of VOC emissions could not be calculated.

Table C-6. SOLVENT CONSUMPTION DATA FOR TREAD END CEMENTING
(Industry Survey II)

Plant Code	Solvent Consumption 1977 Mg	Solvent Consumption 1977 Tons	Solvent Consumption 1978 Mg	Solvent Consumption 1978 Tons	Solvent Consumption 1979 Mg	Solvent Consumption 1979 Tons
A	15.2	16.8	14.2	15.7	12.9	14.2
B	39.7	43.8	37.5	41.4	44.7	49.2
C	5.2	5.8	4.6	5.1	3.2	3.6
E	21.2	23.4	48.1	53.0	39.9	44.0
F	15.1	16.6	21.5	23.7	20.4	22.5
G	5.6	6.1	6.1	6.7	5.2	5.7
H	22.8	25.1	25.2	27.8	17.0	18.8
I	112.4	123.9	100.1	110.4	92.5	102.0
J	43.0	47.4	35.6	39.2	27.2	30.0
K	[a]	[a]	[a]	[a]	[a]	[a]
L	150.8	166.3	134.1	147.9	98.8	109.0
M	15.7	17.3	17.8	19.6	17.7	19.5
N	97.7	107.7	85.3	94.0	60.5	66.7
O	7.5	8.3	9.4	10.4	8.0	8.8
P	[a]	[a]	80.2	88.4	61.6	67.9
R	[a]	[a]	86.9	95.8	36.3	40.0
T	109.9	120.6	123.4	136.0	99.2	109.3
U	18.6	20.5	17.7	19.6	16.7	18.4
W	28.8	31.7	29.9	32.9	26.2	28.8
X	9.7	10.7	10.5	11.6	11.3	12.4
Y	47.5	52.3	61.6	67.9	58.2	64.2
Z	47.7	52.6	47.6	52.5	39.2	43.2
AA	[a]	[a]	[a]	[a]	[a]	[a]
BB	171.5	189.0	171.0	188.6	123.1	135.7
CC	29.8	32.9	27.8	30.8	21.5	23.6
DD	0.9	1.0	0.4	0.4	0.9	1.0
EE	5.4	6.0	7.2	7.9	6.7	7.4
GG	25.3	27.9	48.2	53.2	27.1	29.9
HH	51.2	56.4	45.6	50.3	48.8	53.7
II	54.0	59.6	48.8	53.8	41.4	45.6
JJ	308.2	339.7	288.3	317.8	182.3	208.9

[a] Blank indicates that annual mass of solvent consumption could not be calculated.

Table C-7. SOLVENT CONSUMTPION DATA FOR SIDEWALL CEMENTING

(Industry Survey II)

Plant Code	VOC CONSUMPTION 1977		VOC CONSUMPTION 1978		VOC CONSUMPTION 1979	
	Mg	Tons	Mg	Tons	Mg	Tons
B	[a]		[a]		[a]	
C	8.7	9.6	3.6	3.9	6.4	7.0
D	[a]		[a]		[a]	
E	352.0	388.0	351.5	387.5	289.4	319.0
G	[a]		[a]		[a]	
H	[a]		[a]		[a]	
I	[a]		[a]		[a]	
J	[a]		[a]		[a]	
K	[a]		[a]		[a]	
M	[a]		[a]		[a]	
N	[a]		[a]		[a]	
O	33.9	37.3	337.4	41.3	40.3	44.5
P	[a]		314.9[b]	347.1	370.6[b]	408.5
Q	[a]		[a]		[a]	
R	[a]		[a]		[a]	
S	[a]		[a]		[a]	
T	167.2	184.3	92.4	101.9	92.4	101.8
U	[a]		[a]		[a]	
V	[a]		[a]		[a]	
X	[a]		[a]		[a]	
Y	[a]		[a]		[a]	
Z	131.5	144.9	148.8	164.0	122.3	134.8
AA	[a]		[a]		[a]	
BB	[a]		[a]		[a]	
CC	[a]		[a]		[a]	
DD	[a]		[a]		[a]	
EE	[a]		[a]		[a]	
FF	[a]		[a]		[a]	
GG	[a]		[a]		[a]	
II	[a]		[a]		[a]	
JJ	[a]		[a]		[a]	

[a] Blank indicates that annual mass of solvent consumption could not be calculated.

[b] Includes solvent consumption from bead cementing.

Table C-8. OPERATING PARAMETERS FOR BEAD CEMENTING (Industry Survey I)

Plant Code	Number of bead dipping operations	Exit gas properties: Flow rate, m3/s per operation: Average	Exit gas properties: Flow rate, m3/s per operation: Range	Exit gas properties: Temperature, °C	Exit gas properties: Gauge pressure Pa
A	1	3.0	-[a]	-[b]	0
B	-[c]	-[d]	-[c]	-[c]	-[c]
C	1	0.9	-[a]	-[b]	4
D	-[c]	-[d]	-[c]	-[c]	-[c]
E	-[c]	-[d]	-[c]	-[b]	0
I	1	4.7	-[a]	-[b]	0
K	1	-[d]	-[e]	-[f]	-[f]
L	-[c]	-[d]	-[c]	-[c]	-[c]
M	1	-[d]	-[e]	-[f]	-[f]
O	-[c]	-[d]	-[c]	-[c]	-[c]
P	3	2.4	-[g]	-[b]	4
Q	-[c]	-[d]	-[c]	-[c]	-[c]
R	1	3.6	-[a]	-[b]	0
T	-[c]	-[d]	-[c]	-[c]	-[c]
V	-[c]	-[d]	-[c]	-[c]	-[c]
W	-[c]	-[d]	-[c]	-[c]	-[c]
X	1	-[d]	-[e]	-[f]	-[f]
Y	-[c]	-[d]	-[c]	-[c]	-[c]
Z	-[c]	-[d]	-[e]	-[f]	-[f]
BB	-[c]	-[d]	-[e]	-[f]	-[f]
DD	-[c]	-[d]	-[c]	-[c]	-[c]
EE	-[c]	-[d]	-[e]	-[f]	-[f]
FF	1	-[d]	-[e]	-[f]	-[f]
GG	4	-[d]	-[e]	-[f]	-[f]
HH	-[c]	-[d]	-[c]	-[c]	-[c]
JJ	1	2.4	-[a]	-[b]	2,000
LL	-[c]	-[d]	-[c]	-[c]	-[c]
NN	1	2.4	-[a]	-[b]	1,470
OO	2	3.3	-[a]	21	-[c]
PP	-[c]	-[d]	-[c]	-[c]	-[c]
QQ	-[c]	-[d]	-[c]	-[c]	-[c]
RR	1	-[d]	-[e]	-[f]	-[f]
SS	-[c]	-[d]	-[c]	-[c]	-[c]
TT	-[c]	-[d]	-[e]	-[f]	-[f]
UU	-[c]	-[d]	-[c]	-[c]	-[c]
WW	4	0.1	-[g]	21	0
XX	1	3.8	-[a]	-[b]	0
YY	-[c]	-[d]	-[c]	-[c]	-[c]
ZZ	-[c]	-[d]	-[c]	-[c]	-[c]
AAA	-[c]	-[d]	-[c]	-[c]	-[c]
BBB	-[c]	-[d]	-[e]	-[f]	-[f]
CCC	-[c]	-[d]	-[d]	-[c]	-[c]

[a] Only one value reported.

[b] Ambient.

[c] Not available.

[d] Not calculated.

[e] No invidivuals ventilation system(s).

[f] Not applicable.

[g] All units have same exit gas flow rate.

Table C-9. SOLVENT CONSUMPTION DATA FOR BEAD CEMENTING

(Industry Survey I)

Plant Code	VOC CONSUMPTION		Plant Code	VOC CONSUMPTION	
	Mg	Tons		Mg	Tons
A	3.4	3.7	EE	2.4	2.6
B	[d]	[d]	FF	1.1	1.2
C	73.6	81.1	GG	[d]	[d]
D	[d]	[d]	HH	13.2	14.6
E	7.7	8.5	JJ	59.5	65.6
I	17.9	19.7	LL	[d]	[d]
K	9.3	10.3	NN	93.9	103.5
L	[d]	[d]	OO	15.8	17.4
M	2.1	2.3	PP	[d]	[d]
O	[d]	[d]	QQ	[d]	[d]
P	31.3	34.5	RR	53.2	58.7
Q	[d]	[d]	SS	[d]	[d]
R	106.6	117.5	TT	28.4	31.3
T	13.7	15.1	UU	[d]	[d]
V	[d]	[d]	WW	36.6	40.4
W	[d]	[d]	XX	59.9	66.0
X	7.7	8.5	YY	[d]	[d]
Y	[d]	[d]	ZZ	[d]	[d]
Z	4.0	4.4	AAA	[d]	[d]
BB	[d]	[d]	BBB	2.3	2.5
DD	[d]	[d]	CCC	[d]	[d]

[a] Only one value reported.

[b] Ambient.

[c] Not available.

[d] Not calculated.

[e] No individualized ventilation system(s).

[f] Not applicable.

[g] All units have same exit gas flow rate.

Table C-10. SOLVENT CONSUMPTION DATA FOR BEAD CEMENTING
(Industry Survey II)

Plant Code	VOC CONSUMPTION 1977		VOC CONSUMPTION 1978		VOC CONSUMPTION 1979	
	Mg	Tons	Mg	Tons	Mg	Tons
A	[a]		[a]		[a]	
B	21.8	24.0	8.1	8.9	10.3	11.3
C	22.7	25.0	22.3	24.6	14.9	16.5
D	68.6	45.6	19.0	21.0	15.8	17.4
E	31.2	34.4	31.2	34.4	25.7	28.3
F	[a]		[a]		[a]	
G	[a]		[a]		[a]	
H	15.6	17.2	20.4	22.5	18.7	20.6
I	10.2	11.2	34.3	37.8	7.5	8.3
J	[a]		[a]		[a]	
K	[a]		[a]		[a]	
L	9.3	10.0	9.0	9.9	5.5	6.0
N	[a]		89.9	99.1	98.3	108.3
O	32.9	36.3	37.3	41.1	38.5	42.5
P	4.3	4.7	2.5	2.8	0.6	0.7
Q	3.3	3.6	3.1	3.4	2.9	3.2
R	[a]		[a]		[a]	
S	8.8	9.7	52.0	57.3	28.4	31.2
T	[a]		[a]		[a]	
U	14.1	15.5	15.2	16.8	16.4	18.1
V	33.4	36.8	33.7	37.1	31.5	34.8
W	28.8	31.7	29.9	32.9	26.2	28.8
X	88.3	97.4	[a]		[a]	
U	2.0	2.2	2.0	2.2	2.0	2.2
AA	[a]		[a]		[a]	
CC	[a]		[a]		[a]	
FF	[a]		[a]		[a]	
GG	78.5	86.6	83.5	92.1	77.9	85.9
HH	7.9	8.7	65.5	72.2	47.9	52.8
II	47.9	52.6	49.7	54.8	46.7	51.5
JJ	61.3	67.5	46.2	51.0	43.9	48.4

[a] Blank indicates that annual mass of solvent consumption could not be calculated.

Table C-11. OPERATING PARAMETERS FOR GREEN TIRE SPRAYING
(Industry Survey I)

Plant Code	Number of spray booths	Exit gas properties			
		Flow rate, m^3/s per booth		Temperature, °C	Gauge pressure Pa
		Average	Range		
A	-[a]	-[b]	-[a]	-[c]	0
B	2	3.3	-[d]	27[e]	-[a]
C	2	2.4	1.5-3.3	-[c]	530
D	3	-[b]	-[a]	-[c]	0
E	-[a]	-[b]	-[a]	-[a]	-[a]
I	-[a]	-[b]	-[a]	-[a]	-[a]
K	4	3.0	2.6-3.3	-[c]	0
L	-[a]	-[b]	-[a]	-[c]	0
M	10	8.4	3.1-29.3	-[c]	-[a]
O	7	-[b]	-[a]	-[c]	-[a]
P	6	4.0	1.5-5.7	-[c]	530-2,000
Q	-[a]	-[b]	-[a]	-[a]	-[a]
R	7	3.1	1.5-4.1	-[c]	0
T	-[a]	-[b]	-[a]	-[a]	-[a]
V	8	3.5	-[d]	-[c]	-[a]
W	-[a]	-[b]	-[a]	-[a]	-[a]
X	5	0.9	-[d]	-[c]	0
Y	1	16.8	-[f]	-[c]	0
Z	2	3.7	1.7-5.7	-[c]	-[a]
BB	-[a]	-[b]	-[a]	-[a]	-[a]
DD	-[a]	-[b]	-[a]	-[a]	-[a]
EE	8	3.8	1.3-6.0	-[c]	-[a]
FF	-[a]	-[b]	-[a]	-[a]	-[a]
GG	8	3.8	-[d]	-[c]	-[a]
HH	3	3.9	-[a]	21-29	0
JJ	4	7.0	3.8-11.3	-[c]	930-2,000
LL	13	1.7	1.0-2.8	-[c]	-[a]
NN	2	5.7	-[d]	-[c]	1,470
OO	4	3.0	2.4-3.3	21-38	-[a]
PP	-[a]	-[b]	-[a]	-[a]	-[a]
QQ	1	4.7	-[f]	-[c]	0
RR	-[a]	-[b]	-[a]	-[a]	-[a]
SS	3	3.7	3.6-3.8	13-24	-[a]
TT	8	4.3	1.7-5.7	-[c]	-[a]
UU	-[a]	-[b]	-[a]	-[a]	-[a]
WW	9	5.2	3.2-9.4	21	0
XX	-[a]	-[b]	-[a]	-[a]	-[a]
YY	-[a]	-[b]	-[a]	-[a]	-[a]
ZZ	1	9.9	-[f]	-[c]	0
AAA	-[a]	-[b]	-[a]	-[c]	-[a]
BBB	4	3.4	1.4-5.7	-[c]	-[a]
CCC	3	2.0	0.6-2.7	-[c]	0

[a] Not available.
[b] Not calculated.
[c] Ambient.
[d] All units have same exit gas flow rate.
[e] Maximum value.
[f] Only one value reported.

Table C-12. SOLVENT CONSUMPTION DATA FOR GREEN TIRE SPRAYING

(Industry Survey I)

Plant Code	VOC CONSUMPTION		Plant Code	VOC CONSUMPTION	
	Mg	Tons		Mg	Tons
A	[b]	[b]	EE	433	477
B	30	33	FF	[b]	[b]
C	158	174	GG	457	504
D	439	484	HH	78	86
E	[b]	[b]	JJ	499	550
I	116	128	LL	157	173
K	776	855.5	NN	230	254
L	61	67.3	OO	428	472
M	932	1,028	PP	[b]	[b]
O	624	683	QQ	[b]	[b]
P	512	564	RR	[b]	[b]
Q	502	553	SS	[b]	[b]
R	255	281	TT	444	490
T	[b]	[b]	UU	[b]	[b]
V	475	524	WW	864	953
W	[b]	[b]	XX	[b]	[b]
X	157	173	YY	76	83.8
Y	343	378	ZZ	[b]	[b]
Z	675	744	AAA	28	31
BB	[b]	[b]	BBB	382	421
DD	[b]	[b]	CCC	130	198

[a] Not available.

[b] Not calculated.

[c] Ambient.

[d] All units have same exit gas flow rate.

[e] Maximum value.

[f] Only one value reported.

Table C-13. SOLVENT CONSUMPTION DATA FOR INSIDE ORGANIC SOLVENT-BASED GREEN TIRE SPRAYING

(Industry Survey II)

	VOC CONSUMPTION 1977		VOC CONSUMPTION 1978		VOC CONSUMPTION 1979	
Plant Code	Mg	Tons	Mg	Tons	Mg	Tons
A	63.8	70.3	56.3	62.0	27.6	30.4
B	[a]		[a]		[b]	
C	[a]		[a]		[b]	
D	12.7	14.0	[b]		[b]	
E	[a]		[a]		[b]	
F	[a]		[a]		167.0	184.0
G	[b]		[b]		[b]	
H	[b]		[a]		[a]	
I	[b]		[b]		[b]	
J	[b]		[b]		[b]	
K	[a]		385.3	424.7	506.6	558.4
L	[b]		[b]		[b]	
M	443.6	489.0	441.0	486.1	436.0	480.6
N	362.6	400.0	132.0	145.6	60.0	66.2
O	[a]		[a]		[b]	
P	[b]		[b]		[b]	
Q	[b]		[b]		[b]	
T	180.9	199.4	179.1	197.4	175.6	193.6
V	[b]		[a]		[a]	
W	[b]		[b]		[b]	
Y	[b]		[a]		[a]	
Z	[b]		[b]		[b]	
AA	[b]		[b]		[b]	
BB	[b]		[b]		[b]	
CC	[b]		[b]		[b]	
DD	[b]		[b]		[b]	
EE	[a]		[a]		[b]	
FF	[a]		[a]		[a]	
GG	325.0	358.3	80.8	89.1	[b]	
HH	[b]		[a]		[a]	
II	160.6	177.0	[b]		[b]	

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[a] Blank indicates that annual mass of solvent consumption could not be calculated.

[b] The plant used water-based sprays only.

Table C-14. SOLVENT CONSUMPTION FOR OUTSIDE ORGANIC SOLVENT-BASED GREEN TIRE SPRAYING

(Industry Survey II)

Plant Code	VOC Consumption 1977		VOC Consumption 1978		VOC Consumption 1979	
	Mg	Tons	Mg	Tons	Mg	Tons
A	93.8	103.4	91.5	100.9	107.5	118.5
B	207.7	229.0	235.9	260.0	210.4	231.9
C	a		121.6	134.0	88.4	97.4
D	264.1	291.1	a		a	
E	341.0	375.8	298.2	328.7	271.9	299.7
F	553.7	610.4	550.3	606.6	545.7	601.5
G	214.2	236.1	234.9	260.0	185.8	204.8
H	a		a		b	
I	a		a		b	
J	503.1	554.6	447.2	493.0	a	
K	a		59.0	65.0	b	
L	b		b		b	
M	297.9	328.4	206.3	227.4	192.1	211.7
N	b		b		b	
O	b		b		b	
P	a		a		b	
Q	a		a		b	
R	303.6	334.6	222.6	245.3	31.2	34.4
S	601.3	662.8	525.5	579.3	365.6	402.9
T	a		a		a	
U	520.6	573.9	404.7	446.1	441.8	487.0
V	a		269.2	296.7	492.3	542.7
W	511.3	563.6	596.5	657.5	576.4	635.4
X	749.7	826.4	763.6	841.7	740.6	816.3
Y	496.1	546.9	a		a	
Z	a		882.1	972.4	422.4	465.6
AA	b		b		b	
BB	69.1	76.2	64.0	70.5	35.8	39.5
CC	363.3	400.5	38.4	42.3	b	
DD	a		a		371.8	409.8
EE	714.6	787.7	809.5	892.3	a	

[a] Blank indicates that annual mass of solvent consumption could not be calculated.

[b] The plant used water-based sprays only.

Table C-15. SOLVENT CONSUMPTION FOR INSIDE WATER-BASED GREEN TIRE SPRAYING

(Industry Survey II)

Plant Code	VOC Consumption 1977		VOC Consumption 1978		VOC Consumption 1979	
	Mg	Tons	Mg	Tons	Mg	Tons
A	[a]		[a]		0.0	0.0
B	5.8	6.5	5.6	6.2	4.5	4.9
C	[a]		[a]		[a]	
D	0.0	0.0	0.0	0.0	0.0	0.0
E	0.0	0.0	0.0	0.0	0.0	0.0
F	0.0	0.0	0.0	0.0	0.0	0.0
G	[b]		[a]		0.0	0.0
H	[a]		[a]		0.0	0.0
I	[a]		[a]		0.0	0.0
J	0.0	0.0	0.0	0.0	0.0	0.0
K	[a]		[a]		[a]	
L	[b]		0.0	0.0	0.0	0.0
M	[b]		[b]		[b]	
N	0.0	0.0	0.0	0.0	0.0	0.0
O	[a]		1.2	1.3	8.6	9.4
P	[a]		[a]		0.0	0.0
Q	[a]		[a]		[a]	
R	[b]		5.5	6.0	0.0	0.0
S	0.0	0.0	0.0	0.0	0.0	0.0
T	0.0	0.0	0.0	0.0	0.0	0.0
U	[a]		0.0	0.0	0.0	0.0
V	[b]		[b]		[b]	
W	[a]		[a]		0.0	0.0
X	3.3	3.7	2.3	2.5	2.4	2.6
Y	0.0	0.0	0.0	0.0	0.0	0.0
Z	0.0	0.0	0.0	0.0	0.0	0.0
AA	[a]		[a]		[a]	
BB	[a]		[a]		[a]	
CC	0.0	0.0	0.0	0.0	0.0	0.0
DD	[a]		[a]		[a]	
EE	0.0	0.0	0.0	0.0	0.0	0.0

[a] Blank indicates that annual mass of solvent consumption could not be calculated.

[b] The plant used organic-based sprays only.

Table C-16. SOLVENT CONSUMPTION FOR OUTSIDE WATER-BASED GREEN TIRE SPRAYING

(Industry Survey II)

Plant Code	VOC Consumption 1977		VOC Consumption 1978		VOC Consumption 1979	
	Mg	Tons	Mg	Tons	Mg	Tons
A	[a]		[a]		[a]	
B	[a]		[a]		7.2	8.0
C	[b]		[a]		[a]	
D	8.9	9.8	8.8	9.7	8.9	9.8
E	[b]		[b]		[b]	
F	[b]		[b]		0.0	0.0
G	0.0	0.0	0.0	0.0	0.0	0.0
H	[b]		[b]		0.0	0.0
I	[a]		[a]		7.8	8.6
J	[a]		[a]		5.2	5.8
K	[b]		[a]		[a]	
L	0.0	0.0	0.0	0.0	0.0	0.0
M	[b]		[b]		0.0	0.0
N	0.0	0.0	0.0	0.0	0.0	0.0
O	[b]		[b]		[b]	
P	[b]		[b]		[b]	
Q	2.0	2.3	1.7	1.9	1.6	1.8
R	[b]		0.0	0.0	7.9	8.7
S	[b]		[b]		[b]	
T	[a]		[a]		8.5	9.4
U	[b]		[b]		[b]	
V	[b]		[b]		[b]	
W	[a]		[b]		[b]	
X	[b]		[b]		[b]	
Y	[b]		[b]		0.0	0.0
Z	[b]		[a]		[a]	
AA	[b]		[b]		0.0	0.0
BB	[b]		0.0	0.0	0.0	0.0
CC	[a]		[a]		[a]	
DD	[b]		[b]		[b]	
EE	[b]		[b]		[b]	

[a] Blank indicates that annual mass of solvent consumption could not be calculated.

[b] The plant used organic-based sprays only.

Table C-17. SOLVENT CONSUMPTION DATA AND OPERATING PARAMETERS FOR TIRE BUILDING[a]

(Industry Survey I)

	VOC CONSUMPTION			VOC CONSUMPTION	
Plant Code	Mg	Tons	Plant Code	Mg	Tons
A	a	148	EE	a	281
B	a	a	FF	33	a
C	63	100	GG	a	a
D	a	74	HH	a	13
E	a	153	JJ	61	120
I	a	a	LL	a	a
K	a	a	NN	50	24
L	a	163	OO	a	29
M	a	645	PP	a	238
O	a	295	QQ	a	a
P	53	76	RR	67	72
Q	a	280	SS	a	9
R	a	a	TT	a	88
T	a	a	UU	42	62
V	a	a	WW	a	a
W	a	20	XX	a	488
X	a	11	YY	a	a
Y	a	a	ZZ	a	a
Z	a	112	AAA	a	a
BB	a	9	BBB	a	25
DD	a	a	CCC	a	2

[a] Blanks indicate that the number of machines was not available or that VOC emissions could not be calculated.

Table C-18. SOLVENT CONSUMPTION DATA FOR FINISHING[a]

(Industry Survey I)

Plant Code	VOC CONSUMPTION	
	Mg	Tons
A	a	a
B	a	a
C	17.1	18.8
D	23.7	26.1
E	1.2	1.3
I	a	a
K	17.9	19.7
L	a	a
M	1.4	1.5
O	a	a
P	8.5	9.4
Q	a	a
R	a	a
T	17.2	19.0
V	a	a
W	a	a
X	a	a
Y	116.5	128.4
Z	a	a
BB	3.3	3.6
DD	a	a
EE	0.7	0.8
FF	1.1	1.2
GG	31.4	34.6
HH	3.0	3.3
JJ	99.1	109.3
LL	a	a
NN	12.8	14.1
OO	8.6	9.5
PP	a	a
QQ	a	a
RR	9.8	10.8
SS	11.3	12.5
TT	16.0	17.6
UU	14.9	16.4
WW	a	a
XX	a	a
YY	a	a
ZZ	a	a
AAA	1.1	1.2
BBB	a	a
CCC	2.6	2.9

[a] Blanks indicate that annual mass of VOC emissions could not be calculated.

C.3 CALCULATION OF MEAN EMISSION FACTORS FOR SOLVENT-CONSUMING FACILITIES

Average gram-per-tire emission factors were developed in an effort to illustrate the relative quantities of VOCs emitted from each solvent-consuming process. Three methods of calculation, each dependent upon one of the data sets, were used to generate emission factors for the various tire manufacturing operations. Table C-19 shows the resulting emission factors.

C.3.1 Calculation Methodology for Undertread, Tread-end, Sidewall, and Bead Cementing Operations

Mean emission factors for undertread cementing, tread end cementing, sidewall cementing, and bead cementing operations were calculated from Industry Survey II data. The industry mean gram-per-tire emission factor for each of these four processes was calculated in the following manner:

(1) Annual solvent consumption values, in grams, were totaled for each reporting plant for 1977-1979;

(2) This sum was divided by the total number of finished tires produced at the plant between 1977 and 1979;

(3) Resultant values represented individual plant gram-per-tire emissions factors;

(4) Individual plant emission factors were totaled, and divided by the total number of reporting plants.

C.3.2 Calculation Methodology for Tire Building and Finishing

Mean emission factors for tire building and finishing processes were calculated from Industry Survey I data. The industry mean gram-per-tire emission factors for these operations were derived in the following manner:

(1) Solvent consumption, in grams, was established for each plant;

(2) This value was divided by the total number of finished tires produced at that same plant during the reported year;

(3) Resultant values, representing individual plant gram-per-tire emission factors, are then summed, and divided by the total number of reporting plants.

C.3.3 Calculation Methodology for Inside and Outside Green Tire Spraying

Mean emission factors for inside and outside green tire spraying processes were developed using Industry Survey II data. The industry mean gram-per-tire emission factors for these processes were calculated in the following manner:

(1) Annual water-based green tire spray consumption values for each plant are converted from units of volume to units of mass using vendor- and industry-supplied density values;

(2) Water-based green tire spray mass consumption values are multiplied by the volume percent of VOCs contained in the spray and divided by the total number of finished tires produced;

(3) Solids contained in organic solvent-based green tire sprays are assumed to be in solution; thus the green tire spray mass consumption values are divided directly by the total number of finished tires produced;

(4) Per-tire solvent consumption values for each plant are averaged over 3 years, weighted by tire production; then the 3-year plant averages are totaled and divided by the total number of plants reporting data. (Note: Per-tire inside and outside organic green tire spray values are calculated in a manner similar to that for undertread, sidewall, tread end, and bead cementing);

Through comparison, gram-per-tire emission factors reflect the relative importance of VOC emissions from each tire processing operation. The emission factors are also used in calculating the industry's total VOC emissions and aid in projecting the percent reduction of emissions associated with proposed regulatory alternatives. The gram-per-tire scheme is also utilized to project environmental, economic, and cost impacts from the proposed levels of emission reduction.

TABLE C-19. MEAN EMISSION FACTORS BASED ON SOLVENT CONSUMPTION DATA (1977 through 1979)

Operation	Solvent Use (gms/tire)
Undertread Cementing	63.2
Sidewall Cementing	41.1
Automatic tread-end Cementing	23.8
Manual tread-end Cementing	9.9
Tread-end Cementing Aggregate	15.1
Bead Cementing	8.3
Inside Green Tire Spraying	
Organic Solvent-based	48.2
Water based	0.1
Outside Green Tire Spraying	
Organic Solvent-based	89.0
Water-based	1.4

[a] Where solvent consumption for undertread cementing facilities and sidewall cementing facilities were reported as one figure.

C.4 CALCULATION OF VOC EMISSIONS FROM HIGH-TEMPERATURE TIRE MANUFACTURING OPERATIONS

A temperature-weight loss correlation proposed by S.M. Rappaport has been used to estimate emissions from tire curing. Emissions from other high-temperature tire manufacturing processes are approximated using the ratio of the operating temperature to 180°C (the temperature at which curing emissions were measured) as a correction factor. In addition, the numerical constants must be reduced by a factor of 10 when estimating volatile organic compound emissions, because 90 percent of the weight losses that were observed could be attributed to evaporation of water.* Thus, the modified temperature-weight loss equation is:

$$C = 1.24 \times 10^{-3} T \qquad \text{(C-1)}$$

where C = weight loss, grams per kilogram;
T = operating temperature, °C.

In compounding, the mechanical release of heat normally raises the temperature of the rubber stock to 100°C. Twenty percent of the volatile species emitted are assumed to be adsorbed on carbon black particulate that are simultaneously released. Therefore, the emission factor for compounding is:

$$(0.8)\ (1.27 \times 10^{-3})\ (100) = 0.1 \text{ g/kg} \qquad \text{(C-2)}$$

A representative tire mass is required to convert the emission factor from equation C-2 to grams-per-tire. A passenger car tire was chosen for this purpose because it represents approximately 80 percent of the total number of tires produced by the industry, according to the information shown in Table 3-1. Data supplied by three plants that produce only passenger car tires were used to calculate an average tire mass of 11.5 kilograms. Using this value, the estimated emission factor for compounding is one gram per tire.

C.5 EMISSION TEST ACTIVITIES

C.5.1 Stage 1 Emission Tests

Emission tests were performed at the undertread cementing operation at one plant in order to: (1) determine VOC removal efficiency of the carbon adsorber, (2) determine cement usage, and (3) compare mass emissions using flame ionization detection (FID) method and EPA Method 25. The operation is equipped with a capture system which encloses the cement application area and conveyor leaving the application area. Captured VOCs are vented to a dual bed carbon adsorber.

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*Presentation, R.C. Niles, Uniroyal, Incorporated, to K.J. Zobel, ESED, OAQPS, EPA. September 8, 1977, Durham, North Carolina.

Carbon adsorber removal efficiency was tested using the flame ionization detection (FID) method and EPA Method 25. The removal efficiency agreed closely for both methods. Three one-day tests of the carbon adsorption system removal efficiency were conducted using the FID method. Carbon adsorber inlet and outlet concentrations were measured and compared. The mean inlet concentration was 8.7×10^3 ppmv and the mean outlet concentration was approximately 1.1×10^3 ppmv, for a mean removal efficiency of 87.9 percent. On a mass basis, the removal efficiency for VOC was about 88.7 percent, with a reduction in the mean inlet quantity of 47.8 milligrams per square centimeter (mg/cm^2) of undertread cemented to a mean outlet quantity of 5.39 mg/cm^2. See Table C-20 for a summary of data. Five two-hour tests of the carbon adsorption system were conducted using EPA Method 25. The mean removal efficiency for VOC was 86.7 percent. See Table C-21 for a summary of the test results using EPA Method 25.

Data scatter in the results was attributed to two variables: (1) the type of tread being processed (radial versus non-radial), and (2) variations in the effectiveness of the enclosure, due to length of time the operator needed access to the cement application equipment.

Cement usage data was collected over a two-day period. As shown in Table C-22, there was a wide variation in cement usage between measurement periods. The variation was considered reasonable based on potential process variations during the test period and testing conditions. For example, the cement usage rate varied with respect to the type of tread being processed (radial versus non-radial). It was concluded that the measurement method would be reliable for estimating average cement usage provided that tests are conducted over a sufficient number of days. However, because of the limited amount of data collected at this site, any conclusions about cement usage are limited.

Table C-20. SUMMARY CARBON ADSORPTION SYSTEM--FID

DATE	(1) TOTAL TREAD AREA CEMENTED DURING TEST PERIOD	INLET		OUTLET		REMOVAL(4) EFFICIENCY	REMOVAL(5) EFFECIENCY
		VOC(2) CONCEN-TRATION	VOC MASS(3) PER AREA OF TREAD CEMENTED	VOC(2) CONCEN-TRATION	VOC MASS(3) PER AREA OF TREAD CEMENTED		
	(m^2)	(ppmv)	(mg/cm^2)	(ppmv)	(mg/cm^2)	(%)	(%)
1/23/79	884	9067	59.3	983	5.85	89.2	82.1
1/24/79	2221	8033	47.5	908	5.37	88.7	89.1(6)
1/25/79	2760	8965	36.7	1274	4.94	85.8	89.0(6)
MEAN	1955	8688	47.8	1055	5.39	87.9	86.7

(1) EQUATION A.1 AND PROCESS DATA (CONFIDENTIAL)
(2) FID DATA - APPENDIX D
(3) EQUATION A.2 - EQUATION A.3
(4) BASED ON FID DATA - EQUATION A.4
(5) BASED ON TGNMO DATA - TABLE 3.3 EQUATION A.4
(6) AVERAGE OF TWO SAMPLING RUNS

Table C-21. CARBON ADSORBER EFFICIENCY--EPA METHOD 25

RUN #	INLET (ppmv)	OUTLET (ppmv)	REMOVAL EFFICIENCY (%)
1	4314	774	82.1
2	8845	917	89.6
3	4623	534	88.5
4	5592	779	86.1
5	8614	702	91.9
AVERAGE	----	----	87.6

Table C-22. SUMMARY OF UNDERTREAD CEMENTING USAGE RESULTS

DATE	MASS OF CEMENT	MASS OF CEMENT PER AREA OF UNDERTREAD CEMENTED	INLET VOC MASS PER MASS OF CEMENT USED	OUTLET VOC MASS PER MASS OF CEMENT USED
	(kg)	(mg/cm²)	(kg/kg)	(kg/kg)
1/24/79	439.8	60.6	.81	9.6×10^{-2}
1/25/79	790.4	31.8	1.16	1.54×10^{-1}
MEAN	615	46.2	.99	1.25×10^{-1}

For further detail about these tests see the final test report.**

C.5.2 Stage 2 Emission Tests

Emission tests were performed at the tread end cementing and bead cementing facilities of two plants. The test objectives were: (1) to determine VOC evaporation rates from cemented components, (2) to determine cement usage rates, and (3) to measure VOC mass emissions using FID analysis and EPA Method 25.

C.5.2.1 Tread End Cementing. The tread end cementing operation at Plant Number One was equipped with automatic spray arms, one for each tread end, which are triggered by an electric eye system as the tread passes on a conveyor. At Plant Number Two each tread passes a cementing station on a conveyor belt where cement is manually applied to both bevel-cut ends of the tread. An operator paints the cement on the tread using a sponge which he dips into an open tray containing the cement. After cementing, the treads are conveyed to "bookers" who place the treads onto a series of trays which resemble the pages of an open book.

Each test was performed by taking a freshly cemented tread off the conveyor just after cement application and placing it into a ventilated enclosure as quickly as possible. The ventilated enclosure's exhaust VOC concentration and air volume was measured so a VOC mass emitted from the cemented tread could be calculated. Individual tests were considered complete when the test enclosure VOC concentration had decayed to 5 percent of its peak initial concentration. The length of time required for 90 and 95 percent reduction of the peak VOC "flash off" concentration was also recorded at both plants. The length of time required for 99 percent reduction of the peak VOC "flash off" concentration was also recorded at Plant Number Two; however, due to high background concentrations, too few results could be recorded for any conclusions to be drawn. "Flash off" times are shown below:

**Jongleux, R.F., Volatile Organic Carbon Emission Testing at Armstrong Rubber Company, Eastern Division, West Haven, Connecticut, TRW, Environmental Engineering Division. Durham, North Carolina. April 1979.

Time	Number of Tests	Averaged Flash-Off Time (Seconds)	Range (Seconds)	Standard Deviation (Seconds)
Plant No. 1				
t_{90}	34	82.7	58 to 148	21.5
t_{95}	28	112.0	69 to 204	33.1
Plant No. 2				
t_{90}	47	108	68 to 218	31
t_{95}	33	125	77 to 185	29
t_{99}	6	113	94 to 147	20

Tread end cementing VOC emission results are expressed as mass of carbon emitted (in grams) per unit area (square centimeters) of tread cemented. These results are divided into six categories; VOC(FID)$_{90}$, Flash-Off VOC(FID)$_{90}$, VOC(FID)$_{95}$, Flash-Off VOC(FID)$_{95}$, VOC(FID)$_{99}$, and Flash-Off VOC(FID)$_{99}$. VOC(FID) values represent emissions recorded from initial instrument response (after encosure) to time t_{90}, t_{95}, or t_{99}. Flash-off VOC(FID) values represent emissions from VOC(FID) plus an estimate of emissions from cement application to initial instrument response after placement in the test enclosure. Values are shown below:

VOC Name	Number of Tests	Averaged VOC Mass Per Area (g/cm^2)	Range (g/cm^2)	Standard Deviation (g/cm^2)
Plant No. 1				
VOC(FID)$_{90}$	33	0.0025	0.0009 to 0.0043	0.0006
Flash-off VOC(FID)$_{90}$	33	0.0027	0.0010 to 0.0046	0.0007
VOC(FID)$_{95}$	26	0.0027	0.0020 to 0.0048	0.0007
Flash-off VOC(FID)$_{95}$	26	0.0030	0.0022 to 0.0051	0.0008

VOC Name	Number of Tests	Averaged VOC Mass Per Area (g/cm^2)	Range (g/cm^2)	Standard Deviation (g/cm^2)
Plant No. 2				
$VOC(FID)_{90}$	47	0.0033	0.0011 to 0.0078	0.0019
Flash-off $VOC(FID)_{90}$	47	0.0035	0.0011 to 0.0081	0.0019
$VOC(FID)_{95}$	33	0.0033	0.0011 to 0.0088	0.0019
Flash-off $VOC(FID)_{95}$	33	0.0035	0.0011 to 0.0091	0.0020
$VOC(FID)_{99}$	6	0.0019	0.0015 to 0.0024	0.0003
Flash-off $VOC(FID)_{99}$	6	0.0020	0.0016 to 0.0016	0.0004

During each tread end cementing material balance test run at both plants, the quantity of cement used over a selected time period and the total surface area of treads cemented were measured. Each test period coincided with the duration of a production run for treads of common size and identification number. Material balance test results are shown below:

	Average Cement Usage (g/cm^2)	Range (g/cm^2)	Standard Deviation (g/cm^2)
Plant No. 1	0.017	0.004 to 0.036	0.002
Plant No. 2	0.016	0.013 to 0.019	0.003

VOC mass emitted per mass of cement applied tests were performed using FID analysis and EPA Method 25 in order to measure the VOC mass content of tread end cements used at Plant Number 1 and Plant Number 2. Results are shown below:

VOC mass (g voc as carbon emitted per g of cement dried)

	Tread End Cementing
Plant Number 1	0.95
Plant Number 2	0.84

For more details of the test methodology, see the final test results.***

C.5.2.2 Bead Cementing. Tests were performed at the bead cementing facility at one plant in order to quantify the VOC mass which was emitted by a freshly cemented bead or group of beads, and to correlate this mass with bead surface area upon which the cement was applied. Tests were performed at the bead cementing facilities of the plant at which Stage 1 emissions tests were conducted and at an additional plant, in order to determine the quantity (mass) of cement used for bead production over a selected period of time. This mass was compared to the total bead surface area cemented during the same time period.

The bead cementing facility at Plant No. 1 was composed of two cement-filled tanks which were covered when not in use. Groups of about 50 beads were dipped into the tank at one time and placed on a rack above and behind the tank to dry. Excess cement dripped onto a splash board and dried or was returned to the tank.

The bead cementing facility at Plant No. 2 was part of the bead formation apparatus. An extruder fuses a rubber coating onto continuous strands of wire. The wire/rubber combination exits the extruder as one flat strip. This flat strip then passes over a wheel which is partially submerged in a cement bath. Contact with the wheel causes it to rotate, thereby coating one side of the passing wire/rubber strip with cement.

Bead cementing VOC emission tests were only performed at Plant No. 1, since there was no effective way to directly measure VOC emissions from the application equipment used at Plant No. 2. At plant No. 1, each test was performed by taking one or a pair of

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***Ringquist, D.E., and R.T. Harrison. Volatile Organic Compound Emission Measurements for Tread End Cementing and Bead Cementing at a Tire Manufacturing Plant, Kelly-Springfield Tire Company, Fayetteville, North Carolina. U.S. Environmental Protection Agency. Research Triangle Park, North Carolina.

Rinquist, D.E., and R.T. Harrison. Volatile Organic Compound Emission Measurements for Tread End Cementing and Bead Dipping Operations at a Tire Manufacturing Plant. Armstrong Rubber Company, West Haven, Connecticut. U.S. Environmental Protection Agency. Research Triangle Park, North Carolina.

uncemented beads and manually dipping them into the cement bath. After dipping, beads were withdrawn from the cement bath and allowed to drain for deliberately varied time periods of between 1.1 and 11.2 seconds. The degree to which the beads were allowed to drain prior to being placed in the test enclosure directly affected the VOC mass emitted from them during drying. The freshly cemented beads were placed into the ventilated enclosure for drying in the same manner as for the tread end cementing tests.

The length of time required for 90 and 95 percent reduction of the peak VOC "flash-off" concentration was recorded. A summary of the results is shown below:

Time	Number of Tests	Averaged Flash-off Time (Seconds)	Range (Seconds)	Standard Deviation (Seconds)
t_{90}	37	118	83 to 149	15.1
t_{95}	37	161	111 to 213	24.3

Bead cementing VOC emission results are expressed as mass of carbon emitted (in grams) per unit area (square centimeters) of tread cemented. These results are divided into four categories; $VOC(FID)_{90}$, Flash-off $VOC(FID)_{90}$, $VOC(FID)_{95}$, and Flash-off $VOC(FID)_{95}$. VOC(FID) values represent emissions recorded from initial instrument response (after enclosure) to time t_{90}, t_{95}, t_{95}, or t_{99}. Flash-off VOC(FID) values represent emissions from VOC(FID) plus an estimate of cement application to initial instrument response after placement in the test enclosure. Values are shown below:

VOC Name	Number of Tests	Averaged VOC Mass/Area (gm/cm^2)	Range (gm/cm^2)	Standard Deviation (gm/cm^2)
$VOC(FID)_{90}$	21	0.0347	0.2970 to 0.0413	0.003
Flash-off $VOC(FID)_{90}$	21	0.0370	0.0318 to 0.0432	0.003
$VOC(FID)_{95}$	21	0.0390	0.0327 to 0.0466	0.004
Flash-off $VOC(FID)_{95}$	21	0.0410	0.0348 to 0.0485	0.004

During each bead cementing material balance test run at the two plants, both the quantity of cement used over a selected time period and the total bead surface area cemented were measured. Tests were run over a 4-day period at each plant. Material balance test results are shown below:

	Average Cement Usage (g/cm^2)	Range (g/cm^2)	Standard Deviation (g/cm^2)
Plant Number 1	0.036	0.024 to 0.053	0.009
Plant Numer 2	0.0034	0.0014 to 0.0079	0.0020

VOC mass emitted per mass of cement applied tests were performed using FID analysis and EPA Method 25 to measure the VOC mass content of bead cements used at Plants No. 1 and Plant No. 2. Results are shown below:

	VOC mass (g voc as carbon emitted per g of cement dried) Bead end cement
Plant Number 1	0.77
Plant Number 2	0.97

For more details of the test methodology, see the final test reports.***

***Ringquist, D.E., and R.T. Harrison. Volatile Organic Compound Emission Measurements for Tread End Cementing and Bead Cementing at a Tire Manufacturing Plant, Kelly-Springfield Tire Company, Fayetteville, North Carolina. U.S. Environmental Protection Agency. Research Triangle Park, North Carolina.

Rinquist, D.E., and R.T. Harrison. Volatile Organic Compound Emission Measurements for Tread End Cementing and Bead Dipping Operations at a Tire Manufacturing Plant. Armstrong Rubber Company, West Hanover, Connecticut. U.S. Environmental Protection Agency. Research Triangle Park, North Carolina.

APPENDIX D

EMISSION MEASUREMENT AND CONTINUOUS MONITORING

Appendix D - Emission Measurement and Continuous Monitoring

D-1 Emission Measurement Methods

During the standard support study for the rubber tire manufacturing industry, the U.S Environmental Protection Agency conducted tests at two tire manufacturing plants.

The purposes of this test program were: (1) to determine the amount of cement used at various types of operations within these plants (2) to compare cement usage rates for different methods of cement application for the same operation, (3) to determine the VOC removal efficiency of a carbon adsorption system, and (4) to determine the rate at which VOC emissions evaporated when applied at the various types of operations at these plants. The summary of the results of these tests is described in Appendix C.

To determine the rate of cement usage at each operation of interest, a material balance test procedure was used. The following is a general description of the material balance test procedure; specific details may be obtained from the Emission Test Report Numbers 79-RBM-1, 79-RBM-6 and 79-RBM-7.

The material balance consisted of determining the weight of cement used over a selected time period and the total surface area of the product to which cement was applied during that same time period. The cement usage was determined by pre- and post-weighing the container from which the cement was used. For three operations - two bead cementing and one undertread cementing operation - it was necessary to determine the initial level in the container; and at the end of the test run, refill the container to the initial level and weigh the cement additions. The total surface area of the product cemented was determined as follows: (a) For undertread cementing, the nominal line speed was multiplied by the elapsed time for a tread run and the nominal booking width of the tread. This surface area cemented per tread run was then added together for all tread runs tested. (b) For tread ends cementing, the nominal tread width for each tread size was multiplied by the number of treads of that size and the average tread cemented length. The average tread cemented length was determined from measurements made on several treads. For the manual cement application technique, this value was determined for each tread size; for the spray application technique, a single value was determined for all tread sizes. The surface area cemented per tread run was then added together for all tread runs tested. (c) For bead cementing, the cemented surface area was determined from the nominal wire size and number of turns per bead (obtained from factory specifications) and multiplied by the total quantity of beads cemented.

Cement usage results were reported per surface area cemented to allow comparison of different methods of application. Data were also obtained to relate emission results in terms of nominal weight of the finished tire.

To determine the VOC removal efficiency of the carbon adsorption system, simultaneous emission tests were performed on the inlet and exhaust of the carbon adsorption system using both EPA Method 25 and a flame ionization detector (FID) procedure to determine the VOC concentration and following EPA Methods 1, 2, and 4 to determine volumeteric flow rates. Sampling runs were scheduled to correspond with the adsorption cycle of one of the carbon beds of the two-bed system. Some runs were performed on both beds.

The rate at which VOC emissions evaporated when cement was applied was determined for two types of tread end cementing (one type at each of two plants) and for one type of bead cementing application technique. For tread end cementing, each test was performed by taking a freshly cemented tread off the conveyor just after cement application and placing it in a ventilated enclosure as quickly as possible. The ventilated enclosure exhaust VOC concentration was monitored with a flame ionization detector analyzer (FID), and the air volume was measured with a positive displacement type meter so a mass of VOC could be calculated. Propane was used to calibrate the FID. The VOC concentration was monitored and recorded on a strip chart recorder. Records were maintained of the elapsed time from cement application to tread enclosure, elapsed time to 90 and 95 percent reduction of the peak VOC concentration. It was assumed that the solvent had evaporated 90 and 95 percent within the time specified by the corresponding peak VOC concentration percent reduction.

The evaporation rate for one method of bead cementing was similarly determined; however, because of sampling equipment limitations, the normal plant operation was simulated with a smaller number of beads. This simulation appears to have increased the apparent cement usage per surface area cemented, however it is not certain what effect this would have on the evaporation rate. However, since the apparent cement usage rate was increased, it would appear that the recorded time to evaporate a specified percentage would be greater than normal plant operations.

D.2 PERFORMANCE TEST METHODS

Performance test methods are needed to determine the VOC content of coating and to determine the overall control efficiency of an add-on VOC control system.

D.2.1 Volatile Organic Compound Content of the Coating.

The volatile organic content of the coating may be determined by manufacturer's formulation or from Reference Method 24, "Determination of Volatile Organic Content (as Mass) of Paint, Varnish, Lacquer, or Related Products."

Reference Method 24 combines several ASTM standard methods which determine the volatile matter content, density, and water content of the coatings. From this information, the mass of volatile organic compounds (VOC) per unit mass of coating is calculated. The estimated cost of analysis per coating sample is $150. For aqueous coatings, there is an additional $100 per sample for water content determination. Because the testing equipment is standard laboratory apparatus, no additional purchasing costs are expected.

D.2.2 Control Efficiency of VOC Add-on Control System

If the VOC content of the coatings used exceeds the level of the recommended standard the efficiency of the add-on control system must be determined. This would be used in conjunction with the mass of solvent used to determine compliance with the recommended standard.

For those types of control systems which do not destroy or change the nature of VOC emissions, the recommended procedure is a material balance system where the mass of the VOC recovered by the control system is determined and used in conjunction with the mass of VOC used over the same period of time. The length of time during which this material balance is conducted will be dependent on the Agency's decision on whether to require continual compliance or to demonstrate compliance during an initial performance test. Examples of control systems where this procedure would be applicable are refrigeration and carbon adsorption systems.

For those control systems which alter the VOC emissions (such as incinerators) a different approach is recommended. Ideally, the procedure would directly measure all VOC emitted to the atmosphere. However, this would require measurement of the VOC emissions which escape capture prior to the incinerator (control system) by construction of a complex ducting system and measurement of the VOC emissions exhausting to atmosphere from the control system.

The recommended procedure requires simultaneous measurement of the mass of VOC (as carbon) entering the control system and exiting the control system to the atmosphere. Methods 1, 2, 3, and 4 are recommended to determine the volumetric flow measurements. Reference Method 25 is recommended to determine the VOC (as carbon) concentration. These results are then combined to give the mass of VOC (as carbon) entering the control system and exiting the control system to the atmosphere. The control efficiency of the control system is determined from these data.

The average of three runs should be adequate to characterize the control efficiency of the control system. The length of each run would be dependent on the operational cycle of the control system employed. Minimum sampling time would be in the range of 30 minutes and would be dependent on the size of the evacuated tanks and the sampling rate employed to obtain a sample. The control agency should also consider the representativeness of the solvents used during the test program. Although the actual testing time using Reference Method 25 is only a minimum of 1 1/2 hours, the total time required for one complete performance test is estimated at 8 hours, with an estimated overall cost of $4,000.

D.3 MONITORING SYSTEMS AND DEVICES

The purpose of monitoring is to ensure that the emission control system is being properly operated and maintained after the performance test. One can either directly monitor the regulated pollutant, or instead, monitor an operational parameter of the emission control system. The aim is to select a relatively inexpensive and simple method which will indicate that the facility is properly operated and maintained.

For carbon adsorption systems, the recommended monitoring test is identical to the performance test. A solvent inventory record is maintained, and the control efficiency is calculated every month. Excluding reporting costs, this monitoring procedure should not incur any additional costs for the affected facility because these process data are normally recorded anyway and the liquid volume meters were already installed for the earlier performance test.

For incinerators, two monitoring approaches were considered: (1) directly monitoring the VOC content of the inlet, outlet, and fugitive vents so that the monitoring test would be similar to the performance tests; (2) monitoring the operating temperature of the incinerator as an indicator of compliance. The first alternative would require at least two continuous hydrocarbon monitors with recorders, (about $4,000 each), and frequent calibration and maintenance. Instead, it is recommended that a record be kept of the incinerator temperature. The temperature level for indication of compliance should be related to the average temperature measured during the performance test. The averaging time for the temperature for monitoring purposes should be related to the time period for the performance test, in this case 1 1/2 hours. Since a temperature monitor is usually included as a standard feature for incinerators, it is expected that this monitoring requirement will not incur additional costs for the plant. The cost of purchasing and installing an accurate temperature measurement device and recorder is estimated at $1,000.